Egyptian Journal of Radiology and Nuclear Medicine

RESEARCH Open Access

Role of 3D-CT gastric volumetric study in post-sleeve gastrectomy

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Abstract

Background: Gastric pouch volumetry after sleeve gastrectomy reflects successful surgery. We aimed to assess the impact of gastric pouch volume after sleeve gastrectomy on weight loss.

Method: The study was performed for 30 patients (22 females and 8 males) who underwent sleeve gastrectomy. Their ages ranged from 18 to 47 years. All patients underwent (multi-slice CT) MSCT examination at 12 months after surgery with oral administration of effervescent emulsion. Post-processing in multi-planar reconstruction and 3D reconstruction was performed to all cases. Gastric pouch volume was measured and correlated with body weight, body mass index (BMI), % reduction in excess body weight and Δweight at 1 year.

Results: A significant positive association was found among gastric volume pouch and weight loss ($P = 0.04$), BMI reduction (P value < 0.0001) and Δweight (P value $= 0.013$). A significant inverse association was found among gastric pouch volume and % reduction in excess body weight (P value $= 0.013$).

Conclusion: MSCT gastric volumetry is the gold standard imaging method for assessment of the gastric pouch volume after sleeve gastrectomy. Significant positive association was found among gastric volume pouch and weight loss, BMI reduction and Δweight at 1 year, i.e., in spite of large gastric pouch volume at 1 year, there is adequate weight loss, BMI reduction and Δweight. Yet, significant inverse association was found among gastric pouch volume and % reduction in excess body weight.

Keywords: CT gastric volumetric, Obese, Bariatric surgery, Sleeve gastrectomy

Background

Obesity is the increase in body weight for height and categorized in accordance with the body mass index (BMI), (body weight/squared height kg/m^2), which ranges from under-weight or wasting (< 18.5 kg/m^2) to morbid or severe obesity (≥ 40 kg/m^2). Obese people are facing multiform of inequality and discriminations due to their weight. Obesity raises the risk of chronic disease morbidity such as depression, disability, cardiovascular disease, diabetes type 2, some tumors and mortality [1–3].

Bariatric surgical operation techniques are specified for cases with medically extreme obesity. Currently, those techniques are the most successful and sturdy treatment for obesity. The laparoscopic sleeve gastrectomy (LSG) has been extensively accepted as a primary bariatric surgery and is no longer taken into consideration as investigational [4, 5].

Imaging of bariatric surgery is a challenge. CT plays a major role in postoperative evaluation of patients. CT also shows a great new role in the evaluation of the size of the new postoperative stomach/pouch by 3D tissue volumetry. It ensures exact data concerning gastric volumes and diameters of anastomoses [6].

We aim in this study to evaluate the role of MSCT-based volumetric assessment of gastric sleeves in patients

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after bariatric surgery and correlation between postoperative gastric volume reduction and body weight reduction.

Methods

Over a period of 24 months, form May 2018 till December 2019, the study was performed for 30 patients (22 females and 8 males). Their ages ranged from 18 to 47 years with a median of 34 years and a mean of 33 years (±7.62 years).

Subjects

The patients were collected as postoperative patients underwent sleeve gastrectomy from outpatient clinic, at a private hospital. We excluded cases with recurrent weight gaining after previous gastric reduction procedure and pregnant females. Full history from the patients and full clinical examination, including height and body weight before surgery and 12 months after surgery, was taken by the referring clinician.

Surgical technique

The surgery was done by single operator using 5 parts techniques: sleeve gastrectomy was done using 36 Fr calibration tube (Boogie) starting from 2 to 4 cm from the pylorus toward the gastro-esophageal junction, with no postoperative complications could be detected.

MSCT technique

All patients underwent MSCT examination at 12 months after surgery. The study was performed after approval of the Ethical committee of scientific Research, Faculty of Medicine, Ain Shams University and after taking consent from all patients.

All patients were asked to be fasting for about four to six hours prior to the examination, to have an empty stomach during the study; to minimize imaging pitfalls as filling defects, as well as to reduce the sense of contrast induced nausea. The contrast media used was an effervescent emulsion. The patient swallowed effervescent granules (5 g of (sodium bicarbonate, anhydrous citric acid and anhydrous tartaric acid)) material in a small amount of water (half cup of water) immediately before the procedure to opacify the entire gastric cavity. The patient lied supine on the CT table, and CT abdomen was performed by using 64 channels MSCT helical GE (General Electric) Emotion, WI, USA. Low dose MSCT scan was obtained with 0.12 cm slice width and 0.12 cm slice gap with a scanning time of about 10 s, without need for further patient waiting in the CT machine.

3D CT volumetry images evaluation

Post-processing was performed by using GE 3D workstation (CT Z420). The post-processing entangled multiplanar reconstruction as well as 3D reconstruction from which the estimated gastric volume was calculated.

In addition, the cross-sectional area of the sleeve, the staple line along the greater curvature, and the length of the whole stomach from the hiatus to the pylorus were assessed to detect any complication. The length of the stomach was manually separated into the length of the sleeve and the length of the antrum at the point of the most prominent and persistent diameter change of the stomach. The volumetric study was assessed by two radiologists with 7- and 3-years' experience (RS and DM, respectively) and consensus were obtained to final volumetric data.

Statistical analysis

Data were analyzed using MedCalc statistical software for Windows (MedCalc Software, Mariakerke, Belgium).

1. Data for continuous variables were expressed as either median, interquartile range and range or mean ± standard deviation and as both number and percentage for categorical data.
2. Mann–Whitney U- and Wilcoxon tests were used to evaluate the differences in continuous variables between different groups.
3. CHI- squared test was used for comparison of categorical data between the two groups. Spearman's rank correlation was used to describe the correlations between the different parameters.
4. For all tests, all P values were two-tailed and a P value < 0.05 was considered significant.

Sample size calculation

Sample size was calculated using G*power version 3.1.9.2 based on previous studies; we found mean of BMI (before) = 39.1 kg/m^2 with SD = 13.16 and mean of BMI (after) = 23.49 kg/m^2 with SD = 18.95, and based on our experience, we used a medium effect size = 0.7, with a power of 80% (using paired t-test and alpha of 0.05). As this study was carried out on 1 group and measured BMI before and after Gastrectomy. The sample needed for the study was estimated to be 29 patients; the total sample size was estimated 29 patients [7, 8].

Results

Our study included 30 obese patients (22 females and 8 males). Their ages ranged from 18 to 47 years with a mean (± SD (standard deviation)) of 33 years

(±7.62 years). A significant change was seen between the males and females' number in this study (×2 = 6.53, $P = 0.01$). The median body mass index (BMI) at 12 months was 25.7 which was significantly lower than the median preoperative BMI of 43.4 ($P < 0.0001$) as in Table 1 and Fig. 1a.

The median weight at 12 months was 72 kg that was significantly lesser than the median preoperative weight of 117 kg ($P < 0.0001$) as in Table 1 and Fig. 1b.

Table 1 Comparison of preoperative weight, BMI and excess weight and 12 months postoperative in all patients

	BMI	Weight (kg)	Excess weight (kg)
Preoperative	43.3	117	57
12 months postoperative	25.7*	72*	9*

*The median weight, BMI and excess weight at 12 months were lower significantly than the median preoperative values ($P < 0.0001$)

The median excess body weight at 1-year postoperative was 9-kg that was significantly low in comparison to the median preoperative excess body weight of 57 kg (P value < 0.0001) as in Table 1 and Fig. 1c.

The 12-month postoperative gastric volume ranged from 36 to 307 in all patients with a median of 118.9 and an IQR of 91–168 and a mean (±standard deviation) of 136 (±66.4) Fig. 1d.

The percentage reduction in weight (Δ weight) {calculated as preoperative weight minus 12-month postoperative weight/preoperative weight × 100} ranged from 28.8 to 47% in all patients with a median of 39%, an IQR of 35.2- 41.4% and a mean (±standard deviation) of 38.4% (±4.63%). Body weight measurements at 6 months postoperative were available for 26 patients only. The median body weight at 6 months postoperative was 86 kg which was significantly higher than the median 12-month postoperative weight of 72 kg (P value = 0.0001). The percentage reduction in weight at 1 year was significantly high in comparison to at 6 months (P value < 0.0001) as in Table 2

A significant positive association was found among gastric pouch volume and weight loss at 12 months

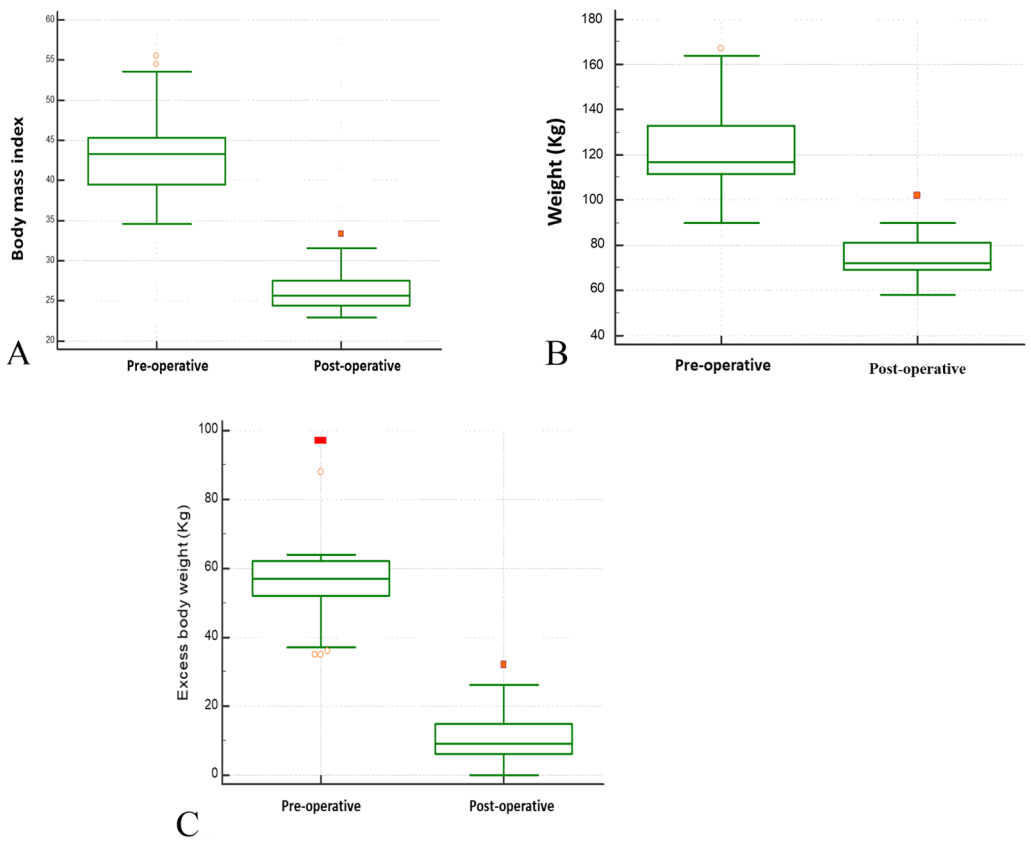

Fig. 1 Box-and-whisker plot of the preoperative and 12-month postoperative BMI **(A),** weight **(B)** and excess weight **(C)** of all patients. Whiskers represent range, bars represent the 25th and 75th percentiles and lines represent median values. Outliers are marked by colored shapes

Table 2 Comparing between 6- and 12-month postoperative weight and the Δ weight in 26 patients

	Weight (kg)	Δ Weight
6 months	86	26.9
12 months	72*	39.9*

*The weight and the percentage reduction in weight at 1 year was significantly high in comparison to at 6 months (*P* value < 0.0001)

($P = 0.04$), BMI reduction (P value < 0.0001) and Δweight (P value = 0.013). A significant inverse association was found among gastric pouch volume and the % reduction in excess body weight at 1 year (P value = 0.013) as in Table 3 and Figs. 2, 3 and 4.

Discussion

Bariatric surgical techniques are indicated for cases with clinically excessive obesity. Recently, those techniques are the most successful management for obesity [9, 10]. According to clinical practice guidelines of the European Association for Endoscopic Surgery (EAES), 2020 indicates that laparoscopic bariatric surgery likely considered for patients with BMI ≥ 40 kg/m^2 and for patients with BMI ≥ 35–40 kg/m^2 with related comorbidities that could be improved with weight loss. Laparoscopic bariatric should be considered for patients with ≥ BMI 30–35 kg/m^2, type II diabetes and/or arterial hypertension with bad control despite optimal medical therapy [11]. Laparoscopic sleeve gastrectomy (LSG) as a standalone method was accompanied with substantial development of health status concerning diabetes, metabolic disorder, high blood pressure, and associated disorders [12, 13]. In the current study, the preoperative median body mass index (BMI) was 43.4 kg/m^2 following the above-mentioned EAES guidelines [11].

This study includes 30 patients (22 females and 8 males) with body mass index (BMI) above 30 kg/m^2. All patients underwent MSCT abdomen with oral contrast at 12-month post-sleeve gastrectomy.

The median body mass index (BMI) at 12 months is 25.7 kg/m^2 which is significantly lower than the median preoperative BMI of 43.4 kg/m^2 ($P < 0.0001$) which agrees with study done by Ferrer-Márquez et al. [14]. They found that at 1-year postoperatively, all cases showed acceptable results regards BMI reduction in comparison to the preoperative values (33.48 ± 5.78 vs. 50.54 ± 6.69 kg/m^2, respectively; $p < 0.001$).

Our patients show median weight at 12 months about 72 kg that is significantly low in comparison to the median preoperative weight of 117 kg ($P < 0.0001$). Also, Pañella et al. [15] found that in comparison with the preoperative measures, the weight reduced significantly at 1-year postoperatively.

The median excess body weight at 12 months postoperative is 9-kg which is significantly lower than the median preoperative excess body weight of 57 kg ($P < 0.0001$). Our result agrees with that of Stier et al. [16] found that the median of excess body weight after operation was 43 kg which was significantly lower than the median preoperative excess body weight of 89.5 kg.

The body weight measurements at 6 months postoperative are available for 26 patients only. The median body weight at 6 months postoperative was 86 kg which is significantly higher than the median 12-month postoperative weight of 72 kg (P value = 0.0001). The percentage reduction in weight at 1 year is significantly higher in comparison to 6 months (P value < 0.0001).

In the same line, Hassan and Elzayat [17] found that patients got acceptable weight loss after surgery with a statistically considerable reduction of the mean weight at 1-year follow-up relative to the mean preoperative weight ($P = 0.001$) as well as to the mean 1-month postoperative weight ($P = 0.009$). At 1-year follow-up, they found good results for the surgery as, the mean weight loss percentage increased from 6.2% ± 38.3 after 1 month to 20.9% ± 12.3 after 1 year.

In our study, we find that a significant positive association is found among gastric pouch volume and weight loss (P value = 0.04), BMI reduction (P value < 0.0001) and Δweight ($P = 0.013$) at 1 year. Significant moderate inverse correlation is found between gastric volume and Δ excess weight at 12 months (rs = 0.45, $P = 0.013$) (Fig. 3, 4).

Table 3 Correlations between the gastric volume and the various parameters and their statistical significance

	Weight at 12 months		BMI at 12 months		Δ weight		Δ excess weight	
	rs	*P* value	rs	*P* value	rs	*P* value	rs	*P* value
Gastric volume	0.37	0.04	0.693	< 0.0001	0.45	0.013	− 0.45	0.013

rs Spearman rank correlation coefficient

A significant positive association was found among gastric size and the weight loss at 12 months ($P = 0.04$), between gastric size and the BMI reduction at 1 year (P value < 0.0001) and among gastric size and Δweight (P value = 0.013). A significant inverse association was found among gastric volume and the % reduction in excess body weight at 1 year (P value = 0.013)

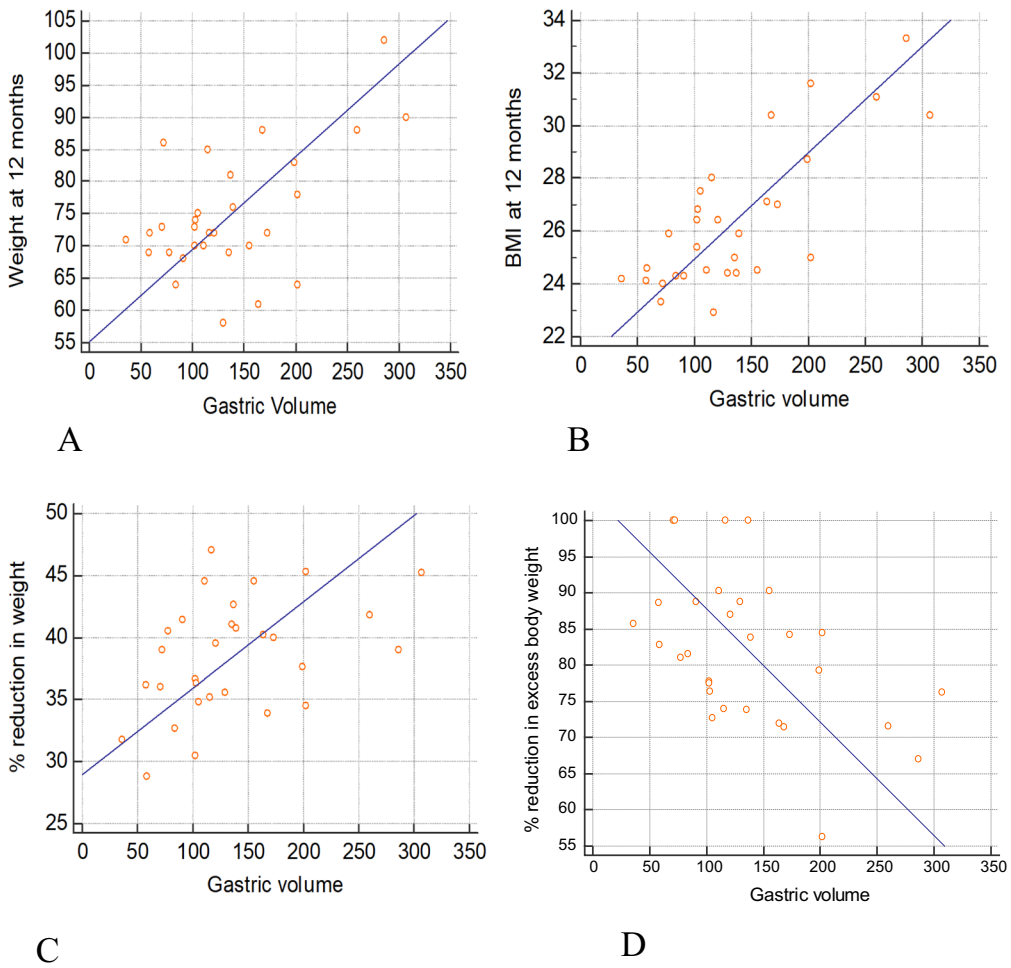

Fig. 2 **A** Scatter diagram revealing a significant mild positive correlation between gastric volume and the weight loss at 12 months (rs = 0.37, *P* = 0.04). **B** Scatter diagram revealing a significant strong positive correlation between gastric volume and the BMI reduction at 12 months (rs = 0.693, *P* < 0.0001). **C** Scatter diagram revealing a significant moderate positive correlation between gastric volume and the Δ weight at 12 months (rs = 0.45, *P* = 0.013). **D** Scatter diagram revealing a significant moderate inverse correlation between gastric volume and the Δ excess weight at 12 months (rs = 0.45, *P* = 0.013)

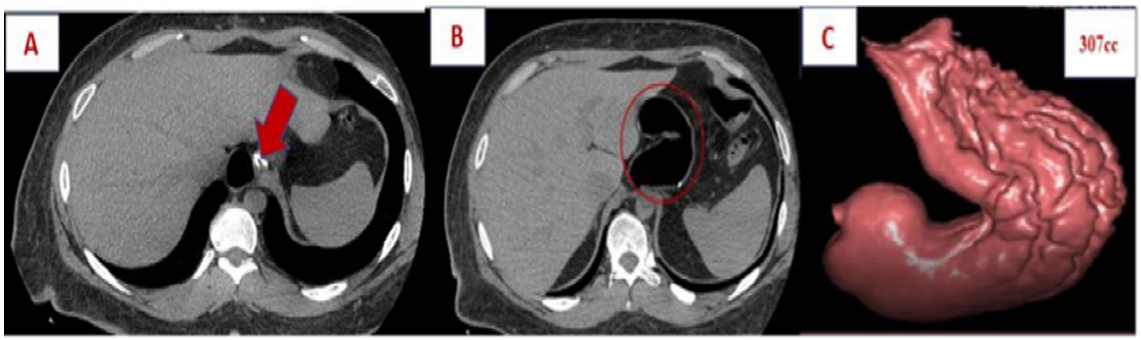

Fig. 3 A 44-year-old obese female (BMI = 55.5) with postoperative gastric pouch volume is 307 cc. Preoperative weight and 1-year postoperative weight were 164 kg and 90 kg, respectively. 1-year weight reduction percentage is 42.5%, and 1-year postoperative BMI is 30.4. Although postoperative gastric volume is high, the patient had successful postoperative weight loss after 1 year but the % of loss from the excess weight after 1 year is 76.2%, i.e., the gastric volume is high and the % reduction in excess body weight is low compared to patients with smaller gastric volume. **A, B** CT abdomen are showing staples (arrow) and gastric pouch (circle). **C** 3D CT gastric volumetry showing gastric volume of 307 cc

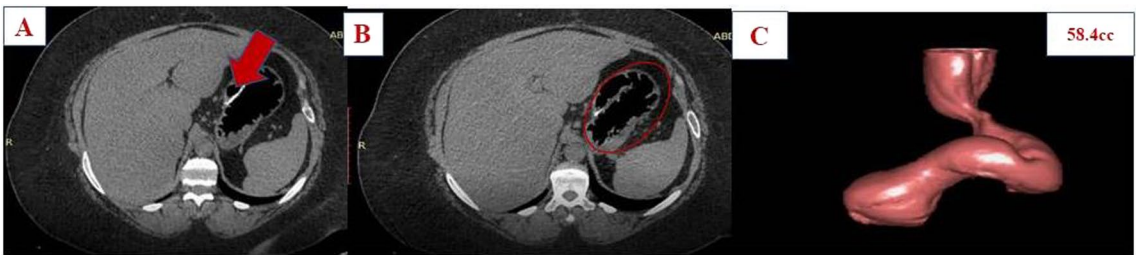

Fig. 4 A 36-year-old obese female (BMI = 37.5) with postoperative gastric volume is 58 cc. Preoperative weight and 1-year postoperative weight was 108 kg and 69 kg, respectively. Weight reduction percentage is 36.2%, and 1-year postoperative BMI is 24.1. Although the postoperative gastric volume is low, the weight reduction percentage at 1 year is low compared to other patients with larger gastric volume but the % of loss from the excess weight after 1 year is 88.6%. **A, B** CT abdomen are showing staples (arrow) and gastric pouch (circle). **C** 3D CT gastric volumetry showing gastric volume of 58.4 cc

Fig. 5 A 34-year-old obese female (BMI = 41.6) with postoperative gastric volume is 91.6 cc. Preoperative weight and 1-year postoperative weight were 116 kg and 68 kg, respectively. Weight reduction percentage is 41.4%, and 1-year postoperative BMI is 24.3. % of loss from the excess weight = 88.8%. **A, B** CT abdomen are showing staples (arrow) and gastric pouch (circle). **C** 3D CT gastric volumetry showing gastric volume of 91.6 cc

Fig. 6 A 41-year-old obese male (BMI = 43.7) with postoperative gastric volume is 121 cc. Preoperative weight and 1-year postoperative were 119 kg and 72 kg, respectively. Weight reduction percentage is 39.5%, and 1-year postoperative BMI is 26.4. % of loss from the excess weight = 87%. **A, B** CT abdomen are showing staples (arrow) and gastric pouch (circle). **C** 3D CT gastric volumetry showing gastric volume of 121 cc

Our cases showing reduction in 1-year postoperative BMI, weight, excess body weight and the percent reduction in weight Figs. 5, 6, 7 and 8

Discordant to our results, Mohamed et al. [18] and Shalaan et al. [19] found that correlation between the body weight and gastric volume measured pre- and postoperatively in the investigated cases was insignificant which means that the stomach volume does not have a direct impact on the body weight. The correlation between body weight reduction percentages (the percentage of body weight reduction were 15%. (7%-24%)) and gastric volume reduction percentage [percentage of operative gastric volume reduction were 84% (76%-98%)], in the investigated cases is found to be insignificant.

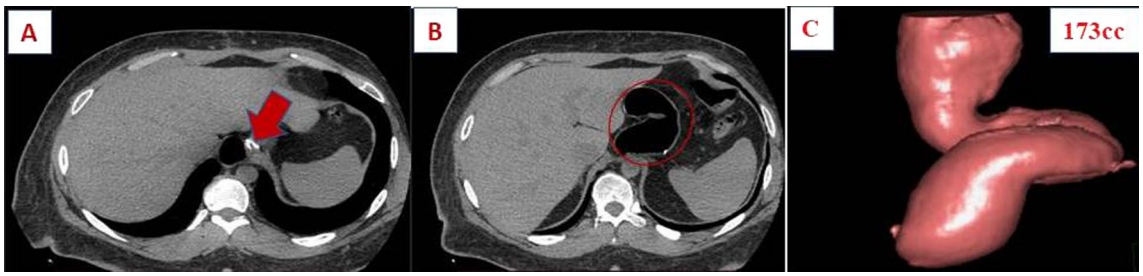

Fig. 7 A 30-year-old obese male (BMI = 45.2) with postoperative gastric volume is 173 cc. Preoperative weight and 1-year postoperative weight were 120 kg and 72 kg, respectively. Weight reduction percentage is 40%, and 1-year postoperative BMI is 27% of loss from the excess weight = 84.2%. Although the postoperative gastric volume is high, the patient weight loss after 1 year is high. **A, B** CT abdomen are showing staples (arrow) and gastric pouch (circle). **C** 3D CT gastric volumetry showing gastric volume of 173 cc

Fig. 8 A 29-year-old obese male (BMI = 46) with postoperative gastric volume is 199.4 cc. Preoperative weight and 1-year postoperative weight were 133 kg and 83 kg, respectively. Weight reduction percentage is 37.6%, and 1-year postoperative BMI is 28.7. % of loss from the excess weight = 79.3%. Although the postoperative gastric volume is high, the patient weight loss after 1 year is high. **A, B** CT abdomen are showing staples (arrow) and gastric pouch (circle). **C** 3D CT gastric volumetry showing gastric volume of 199.4 cc

Concordant to our results, Elbanna et al. [20] concluded that the volume of the residual gastric pouch had significant influence on %Excess Weight Loss afterward LSG. A negative correlation between the volume of remaining gastric pouch after LSG and %EWL at 6 months postoperatively was noted (P value < 0.00001).

Also concordant to our results, Vidal et al. [21] showed a direct positive relationship regarding the correlation between increase in gastric reservoir size and a lower weight losing postoperative in 1- and 12-month period postoperatively; this showed the importance of gastric volume postoperatively in achieving weight loss and that effect can be reduced by increase in the reservoir volume.

Also, other studies found that weight regain after LSG almost after 24 months. The reason is likely due to the weight loss post-LSG is not only due to the limited effect of the surgery, but also related to definite neurohormonal changes. Demerdash et al. found a positive correlation between postoperative BMI and serotonin as well as leptin and negative correlation with ghrelin levels [22].

An increase in gastric volume was not associated with reduced weight loss due to other factors other than the gastric volume, like the lifestyle of the patient including the dietary habits, have impact on the weight loss during the first-year postoperative. Elzayat et al. reported that the mean CT volume of the gastric pouch at 1-year follow-up showed a statistically increase relative to the mean CT volume of the gastric pouch at 1 month postoperative ($P = 0.0024$). During the 1-year follow-up, the gastric pouch volume gradually increased in all patients, which focus attention on the continuous need of dietary regimen and adequate postoperative lifestyle [17]. Also, other factors that positively influence weight loss following LSG include the plasmatic ghrelin levels reduction with LSG confers to satiety, lower stimulation of appetite, and consequently weight loss [23]. The pyloric antrum resection might also be associated with increase in gastric emptying with no increase in gastro-esophageal reflux or the risk of leaks [24]. Also, the quickened gastric emptying has been suggested to be associated with enhanced postprandial cholecystokinin and glucagon like peptide-1 concentration could contribute to improved weight loss and glucose metabolism [25].

The rate of complication post-LSG varying from 0 to 18%, with a 30-day postoperative mortality ranging from 0 to 0.4%. The postoperative complications are divided into early and late. Early postoperative complications including bleeding, gastric leak, obstruction, abscess formation, wound infection in addition to all other possible

postoperative complications of major laparoscopic surgeries. Late postoperative complications of LSG are the development of a fistula, stenosis, GERD, weight loss failure, intrathoracic sleeve migration, and nutritional deficits [26]. No complication was reported in our study neither early nor late.

There are some limitations in our study. One of the limitations is limited number of patients and single medical center study. Also, lack of preoperative MSCT data, to evaluate the preoperative gastric volume, is one of the limitations. Preoperative gastric volumetry was not performed to minimize radiation exposure because our main concern in this work was to evaluate the postoperative pouch volume and its relation to weight loss. Furthermore, the short follow-up interval [1 year] precludes recognizing the delayed increase in gastric size and possible association with weight change. So, longer follow-up is needed.

Conclusions

Gastric volumetry is the gold standard imaging method for assessment of the gastric pouch volume after sleeve gastrectomy. Significant positive association was found among gastric volume pouch and weight loss, BMI reduction and Δweight at 1 year. Yet, significant inverse association was found among gastric pouch volume and % reduction in excess body weight.

Abbreviations

MSCT: Multi-slice computed tomography; EAES: European Association for Endoscopic Surgery; BMI: Body mass index; LSG: Laparoscopic sleeve gastrectomy; EWL: Excess weight loss; rs: Spearman rank correlation coefficient; Fr: French.

Author contributions

DM wrote the manuscript and data collection. KE participated in its design. WH and DM image processing and collection of patient's images. AM conceived the study and participated in its design and coordination. RS participated in the design of the study and performed the statistical analysis and helped to draft the manuscript. All authors have read and approved the manuscript.

Funding

No funding sources.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the ethical committee of "Research Ethics Committee at the Faculty of Medicine, Ain Shams University".

Consent for publication

All patients included in this research gave written informed consent to publish the data contained within this study.

Competing interests

The authors declare that they have no competing interests.

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Received: 16 November 2021 Accepted: 9 June 2022
Published online: 24 June 2022

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