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ORIGINAL CONTRIBUTIONS

Sleeve Gastrectomy: Does the Amount of Stomach Removed Matter?

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Abstract

Purpose Data regarding the associations between percent weight loss and the volume and weight of stomach resected during sleeve gastrectomy (SG) are mixed. The purpose of this study was to evaluate the effect of the size and volume of stomach removed during laparoscopic SG on percent total body weight lost (%TBWL).

Methods An observational case series study was performed on 67 patients for 1 year after SG at a single university-affiliated, tertiary care hospital. Data were collected on demographics, medical history, and %TBWL at 3, 6, and 12 months post-operatively. Pearson's correlation matrices and multiple linear regression analyses were performed.

Results Most patients (88.1%) were female with a mean age of 44 years. The mean volume of stomach resected was 1047.0 cubic centimeters, and the median weight resected was 123.0 g. Follow-up data were available for 44 patients at 1-year post-operation. There was no association between the volume and weight of stomach resected and %TBWL at 1-year post-operation; however, greater %TBWL was associated with younger patient age ($r = -0.525$, $p < 0.001$).

Conclusion One year after SG, no associations between %TBWL and the volume and weight of stomach resected were observed.

Keywords Sleeve gastrectomy · Bariatric surgery · Weight loss · Obesity · Predictors

Introduction

One surgical option for weight loss, the sleeve gastrectomy (SG), was the most commonly performed bariatric surgery as of 2017 [1]. This procedure has been associated with an average percent excess weight loss (%EWL) of 78% (89.3 lbs) 1 year after the procedure [2], as well as improvements or cure of diabetes mellitus, hypertension, hyperlipidemia, and obstructive sleep apnea [3, 4]. However, patients do not always achieve 50% or more EWL after SG, which is considered treatment failure [5]. Sustained weight loss also varies at 5 years post-operation, ranging from 40 to 67% EWL [6]. A variety of possibilities for these differences in short- and long-term %EWL have been explored, including age and sex effects, pre-operative weight loss, pre-operative BMI, pre-operative stomach volume, size of bougie used during surgery, the compliance of the stomach after insufflation, the distance from

Key Points
- Neither weight nor volume of stomach resected correlated with %TBWL 1-year post-SG.
- Younger patient age was correlated with greater %TBWL 1-year post-SG.
- Lower pre-operative BMI was not correlated with greater %TBWL 1-year post-SG.
- Sex was not correlated with %TBWL post-SG, but 88% of the population was female.

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the pylorus to the beginning of the staple line, the volume and weight of stomach resected, and the volume of stomach remaining after surgery [7–17].

While female sex, age greater than 45 years, and higher pre-operative BMI have been associated with less post-operative weight loss [7, 8], no associations have been found between size of bougie used during SG and %EWL [9]. Studies have indicated that a greater distance from the pylorus to the beginning of the resection staple line is associated with lower %EWL and lower % total body weight loss (%TBWL) 1 and 2 years after SG [10, 11, 18]. While pre-operative stomach volume and compliance during insufflation do not appear to correlate with post-operative weight loss [12], data regarding weight loss associations with the volume and weight of stomach resected are mixed [13–15]. One study indicated that resecting volumes less than 1600 cubic centimeters (ccs) in males and 1200 ccs in females was associated with lower % EWL [13]. However, in another study, where the volume of resected stomach varied from 1400 to 1600 ccs for both males and females, there was no correlation between the volume of stomach resected and %EWL 1 year after surgery [14]. A third study evaluated the weight of the resected stomach, indicating that when the resected region weighed 144 g or more, %EWL increased [15]. Regarding residual stomach volume after SG, a recent meta-analysis indicated that 25% of the variability in %EWL after SG can be attributed to variations in residual stomach volume [16]. Furthermore, the volume of the stomach may increase within 1 year after SG, which has been associated with reductions in long-term %EWL [17]. Overall, the size of the stomach, including the volume resected, weight resected, and the residual volume at different time points after surgery, is of interest to clinicians because there may be correlations to SG success. Given the mixed data surrounding associations between the volume and weight of stomach resected during SG and post-operative weight loss, this study aimed to evaluate if the volume and/or weight of stomach resected during laparoscopic SG correlated with %TBWL 1 year after surgery.

Methods

Participants

All adult patients who underwent vertical SG for severe obesity at a single community-based tertiary care hospital from January 1, 2019, to December 31, 2019, and were followed through December 31, 2020, were initially included in this retrospective cohort study. Patients were excluded if the volume and/or weight of stomach resected was not recorded. In total, 67 patients met the inclusion and exclusion criteria for this study.

Study Procedures

This study was approved by the Ascension Via Christi Hospitals Wichita, Inc. Institutional Review Board. Demographic variables (age, sex, and race) and pre-operative height, weight, BMI, and medical comorbidities were reported for each patient. During the procedure, the resection was started 4 cm proximal to the pylorus, and a 32-French bougie was used. A fairly tight sleeve was made around the bougie, and there was no oversewing of the staple line. The absolute size and volume of stomach resected were obtained from the hospital's pathology department. The resected stomachs were weighed while dry, and the absolute volume of resected stomach was determined via hanging method. Post-operative data was collected to evaluate patient weight loss and BMI at 3, 6, and 12 months.

Statistical Analysis

Interval/ratio level data were summarized by calculating means and standard deviations when normally distributed or medians and interquartile ranges for skewed data. Nominal data were summarized by counts and proportions. A Pearson's correlation matrix was computed between eight variables. A multiple linear regression was computed to predict %TBWL at 1 year with age, sex, pre-operative BMI, weight of resected stomach, and volume of resected stomach. All analyses were conducted using SPSS release 19.0 (IBM Corp., Armonk, New York).

Results

Of the 67 patients included in this study, the mean age was 43.6 years and 88.1% were female (Table 1). The median pre-operative weight was 112.5 kg, and the median pre-operative BMI was 41.2 kg/m^2. The mean volume of stomach resected was 1047.0 ccs, and the median weight resected was 123.0 g. Follow-up data were available for 59 patients (88.1% of the initial study population) at 3 months, 51 patients (76.1%) at 6 months, and 44 patients (65.6%) at 12 months post-operation. Among patients with follow-up data available at the 1-year mark, the mean body weight was 89.3 kg with a mean %TBWL of 25.9%.

Correlation analyses indicated that there were no significant associations between volume of stomach resected and weight of stomach resected and %TBWL at any of the follow-up intervals studied (Table 2). However, significant positive correlations were found between pre-operative BMI and the weight and volume of stomach resected ($r = 0.252$ and 0.260, respectively). Younger patient age was also correlated with %TBWL at 12 months ($r = -0.525$). Percent

Table 1 Demographics, pre-operative, operative, and follow-up weight loss data

Parameter	Value
Number of observations	67 (100%)
Age (years)	43.6 ± 11.3
Female sex	59 (88.1%)
Race	
White	50 (74.6%)
Black	12 (17.9%)
Hispanic	3 (4.5%)
Unknown	2 (3.0%)
Pre-operative weight (kg)	112.5 (105.6–127.9)
Body mass index (kg/m2)	41.2 (38.5–46.7)
Diabetes mellitus	
No	46 (68.7%)
Yes, non-insulin-dependent	16 (23.9%)
Yes, insulin-dependent	5 (7.5%)
Hypertension	32 (47.8%)
Sleep apnea	30 (44.8%)
Gastroesophageal reflux disease (GERD)	23 (34.3%)
Hyperlipidemia	13 (19.4%)
Volume of resected stomach (ccs)	1,047.0 ± 293.8
Weight of resected stomach (g)	123.0 (106.0—143.0)
Number of patients with 3-month follow-up	59 (88.1%)
Patient weight at 3 months (kg)	103.0 ± 20.0
3-month percent of total body weight loss	13.2% ± 5.0%
Number of patients with 6-month follow-up	51 (76.1%)
Patient weight at 6 months (kg)	94.5 ± 19.4
6-month percent of total body weight loss	20.7% ± 7.0%
Number of patients with 1-year follow-up	44 (65.7%)
Patient weight at 1 year (kg)	89.3 ± 25.0
1-year percent of total body weight loss	25.9% ± 10.1%

Data are presented as *n* (%), mean ± SD, or median (IQR)

total body weight loss at 3- and 6-month post-operation correlated with %TBWL at 1 year. On multivariate analysis, age was the only variable significantly associated with %TBWL at 1-year post-operation ($P = 0.001$) (Table 3).

Discussion

Main Study Findings

In evaluating factors associated with greater %TBWL at 1 year after SG, there was a moderate correlation with younger patient age. However, sex, pre-operative BMI, weight of resected stomach, and volume of resected stomach were not correlated. These findings add to a body of mixed literature regarding demographic and surgical factors potentially associated with post-SG weight loss [7, 8, 13, 15].

Influence of Age and Sex on %TBWL

Previous findings suggested that patients younger than 45 years lose more weight by 1 year after SG than patients over 45 years [8], which is consistent with the moderate correlation between %TBWL and younger age ($r = -0.525$, $P < 0.001$) noted in the current study. Hypotheses for these associations between younger age and improved SG outcomes center around age-related metabolism changes and age-associated differences in physical activity levels [19]. Additionally, given that most of the current study population (88.1%) was female, age-related menopausal factors could be contributing to the age and %TBWL associations observed in the current study. Decreases in estrogen levels and lifestyle changes associated with menopause are linked to an increased tendency to gain weight, difficulty achieving weight loss, and an increased tendency to regain lost weight among obese and peri- and post-menopausal females [20, 21]. Indeed, previous studies have indicated that there is an association between female sex and lower %EWL after SG [7]. While no such associations between sex and %TBWL were observed in the current study, these findings are likely influenced by a small, predominantly female, sample that was followed for 1-year post-operation.

Influence of Pre-operative BMI on %TBWL

Outside of age and sex, previous studies have indicated that patients with higher pre-operative BMIs achieve less %EWL but greater %TBWL after SG compared to patients with

Table 2 Correlation of weight and volume of resected stomach with % total body weight loss (%TBWL)

	Parameter	1	2	3	4	5	6	7
1	Age							
2	Female	−0.112						
3	Pre-operative BMI	−0.061	−0.011					
4	Weight of resected stomach	−0.062	−0.205	0.252*				
5	Volume of resected stomach	−0.095	−0.261*	0.260*	0.653‡			
6	3-month %TBWL	−0.142	0.070	0.019	−0.036	−0.044		
7	6-month %TBWL	−0.156	−0.028	−0.237	−0.108	−0.100	0.799‡	
8	1-year %TBWL	−0.525‡	0.218	−0.014	0.004	0.035	0.584‡	0.723‡

*$P < 0.05$, †$P < 0.01$, ‡$P < 0.001$

Table 3 Multiple linear regression of relationships between independent variables and percent of total body weight loss at 1-year post-operation

Independent variables	*B*	Standard error	Beta	*P* value
Age	−0.004	0.001	−0.505	0.001
Female	0.050	0.040	0.171	0.225
Pre-operative BMI	0.000	0.003	−0.008	0.960
Weight of resected stomach	0.000	0.000	−0.059	0.740
Volume of resected stomach	2.125E-5	0.000	0.064	0.747
Constant	0.417	0.118	—	0.001

$n=44$; adjusted $r^2=0.213$

lower pre-operative BMIs [7, 14, 18]. However, in the current analysis, there was no association between %TBWL and pre-operative BMI. Given that the previous study analyzing associations between %TBWL and pre-operative BMI had a much larger sample size than the current study (1574 vs 44), these discordances between the findings of the previous and current studies are likely influenced by the small sample size of the current study [18].

Influence of Weight and Volume of Resected Stomach on %TBWL

Although previous studies have produced mixed data regarding associations between the weight and/or volume of stomach resected during SG and %EWL [18–20], the current study indicated that there was no association between %TBWL and these factors. In previous studies, pre-operative stomach sizes have varied from 600 to 2000 ccs, with the mean volume of 785 ccs resected during SG [22]. Reasons for these variations in stomach size among severely obese adults are not entirely clear, but patient height is thought to play a role [18]. Based on height differences between males and females, one previous study has suggested that resections greater than or equal to 1200 ccs for females and 1600 ccs for males are required to achieve adequate weight loss after SG [18]. In the current study, the mean volume of stomach resected was 1047.0 ccs (SD = 293.8 ccs), but the mean %TBWL 1 year after surgery was 25.9%, which is considered successful %TBWL after SG [18]. However, while the average patient in the current study successfully lost weight 1 year after SG, there was neither correlation nor association between the volume of stomach resected and %TBWL after surgery ($r=0.035$, $P=0.747$). These differences between the previous and current study could be due to differences in how the volume of resected stomach was measured, as the previous study measured stomach volumes intra-operatively [13], whereas in the current study, absolute stomach volumes were measured post-operatively via hanging volumes. Alternatively, the lack of association between %TBWL and absolute volume of stomach resected in the current study could be related to the smaller mean volume of stomach resected (1047.0 ccs) in the current study than what was recommended (1200 to 1600 ccs) [13]. Interestingly, a different previous study that measured resected stomach volume intra-operatively did not find an association between resected stomach volume and %EWL 1 year after SG [12].

A third study evaluated associations between %EWL and the volume of resected stomach, which was measured via filling the hanging, resected stomach with water. This study reported no association between resected stomach volume and %EWL 1 year after SG [4]. This technique to measure the resected stomach was similar to the hanging technique used in the current study, and these previous findings are consistent with those of the current study. Interestingly, the previous study indicated that larger volumes of resected stomach correlated with greater pre-operative BMI [14], as was found in the current study ($r=0.260$, $P<0.05$). The previous study noted that pre-operative BMI negatively correlated with %EWL at 1-year post-operation; however, in the current study, there was no association between pre-operative BMI and %TBWL at 1 year. This could be related to differences in how these two outcomes are calculated or reflect the small sample size of the current study.

Regarding the weight of stomach resected, a previous study indicated that when the resected stomach weighed 144 g or more, %EWL was greater [15]. The median weight of resected stomach in the current study was 123.0 g (interquartile range from 106 to 143 g); however, no associations between the weight of resected stomach and %TBWL 1 year after SG were noted ($r=0.004$, $P=0.978$). Both the previous study and the current study demonstrated significant variability in the weights of stomach resected [15]. However, the previous study was different from the current study in that resected stomachs were weighed intra-operatively [15], whereas they were weighed dry post-operatively in the current study. These technical differences could be contributing to the different findings between these two studies. Alternatively, the lack of association between weight of resected stomach and %TBWL in the current study could be related to resecting less stomach in the current study than in the previous study (123 g vs 144 g) [15]. This previous study also indicated that patients with greater pre-operative weights had heavier resected stomach segments [15], which is similar to the observed associations between higher pre-operative BMIs and heavier resected stomach specimens in the current study ($r=0.252$, $P<0.05$).

While there were no associations between the weight and volume of stomach resected during SG and %TBWL at 1-year post-operation, the findings from the current study are still valuable to surgeons. These results indicate that at least one demographic factor, younger patient age, is associated with greater %TBWL after SG, whereas the amount of stomach resected during surgery is unlikely to influence outcomes.

Limitations

The sample size of the current study was small ($n=67$), and complete follow-up data were only available for 44 patients 1 year after SG, potentially limiting generalizability and our ability to detect significant findings. Additionally, the study population was predominantly female (88.1%). Regarding the volume and weight of stomach resected, vast differences in pre-operative stomach size and volume have been reported [22], which could influence the absolute volume and weight of stomach resected. Unlike resected stomach volume and weight, pre-operative stomach size is difficult to quantify. Therefore, pre- and post-operative measures of in vivo stomach size were not included in the current study. Additionally, much of the previous SG outcome literature has used %EWL as a measurement of post-operative weight loss, but more recent updates recommend transitioning to %TBWL, as was used in the current study. It is difficult to precisely compare previous data using %EWL to the current study's results because %EWL includes ideal body weight in the calculation while %TBWL does not. Overall, future research would benefit from analyses between the pre- and post-operative stomach size, resected stomach volume and weight, and %TBWL after SG with larger, more diverse study populations that are followed for more than 1 year. In particular, a longer follow-up period would demonstrate whether successful weight loss at 1 year was sustained.

Conclusions

During SG, neither the weight nor the volume of stomach resected appears to be associated with the %TBWL at 1-year post-operation, unlike age. These findings add to literature regarding patient and surgical factors associated with %TBWL after sleeve gastrectomy.

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Author Contribution

Author	Study conception and design	Data collection	Data analysis	Data interpretation	Draft manuscript preparation	Manuscript critical revision	Manuscript final approval	Accountability for accuracy and integrity of work
Winter	X	X		X	X	X	X	X
Falk	X	X		X	X	X	X	X
Alderson	X	X		X		X	X	X
Quinn	X		X	X		X	X	X
Helmer	X			X		X	X	X
Brown	X			X		X	X	X

Declarations

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Consent to Participate Informed consent does not apply.

Conflict of Interest The authors declare no competing interests.

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