Five-Year Outcomes of Endoscopic Sleeve Gastroplasty for the Treatment of Obesity

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BACKGROUND AND AIMS: **The growing burden of obesity as a chronic disease necessitates a multifaceted approach to management. There has been an increase in the number of available endoscopic therapies for weight management with endoscopic sleeve gastroplasty (ESG) proving to be one of the best options. The long-term efficacy of ESG for management of obesity is not known. This study sought to assess the long-term safety and efficacy of ESG for treatment of obesity.**

METHODS: **This was a prospective cohort study. Participants underwent ESG in a single academic center, and were prospectively enrolled. All procedures were performed by the same therapeutic endoscopist. Patients with a body mass index of >30 kg/m2 (or >27 with comorbidities), who underwent ESG from August 2013 to August 2019 for treatment of obesity were enrolled. Patients were followed for up to 5 years after their procedure. The primary outcome was weight loss at 5 years after the procedure (% total body weight loss, TBWL)**

RESULTS: **216 patients (68% female) with a mean age of 46±13 years, and mean BMI of 39±6 kg/m^2 underwent ESG. Out of 216 patients, 203, 96, and 68 patients were eligible for a 1-, 3-, and 5-year follow up, with complete follow-up rates of 70%, 71%, and 82%, respectively. At 5 years, mean TBWL was 15.9% (95% CI, 11.7-20.5, p < .001) and 90 and 61% of patients maintained 5 and 10% TBWL, respectively. There was an overall rate of 1.3% moderate adverse events (AEs), without any severe or fatal AEs.**

CONCLUSIONS: **Our results suggest that ESG is safe and effective for treatment of obesity, with durable long-term results for at least up to 5 years after the procedure. This procedure should be considered as a reliable option for treatment of obesity.**

Keywords: Obesity; Therapeutics; Gastroplasty; Endoscopy; Bariatrics.

The growing burden of obesity as a chronic disease, both globally and in the United States, necessitates a comprehensive and multifaceted approach to prevention and management.[1] It is well known that patients with obesity achieve only modest and short-lived improvement by following lifestyle recommendations, and most of the qualifying patients never undergo bariatric surgery, given issues with access and cost, and fear of its associated real and perceived morbidity.[2] Although there has been a significant increase in the pharmacotherapy options for weight management over the past decade, even the best available medications still achieve only 10% or less total body weight loss (TBWL), and up to half of patients taking medication for a year fail to achieve a 5% TBWL.[3-5] Meanwhile, there has been a significant increase in the number of available endoscopic therapies for weight management over the past decade,[6] with endoscopic sleeve gastroplasty (ESG) proving to be

Abbreviations used in this paper: AE, adverse event; BMI, body mass index; CI, confidence interval; ESG, endoscopic sleeve gastroplasty; EWL, excess body weight loss; TBWL, total body weight loss.

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one of the widely available options given its safety and short to mid-term effectiveness.

ESG is a minimally invasive endoscopic procedure, during which endoscopic full-thickness suturing is used to approximate the anterior and posterior walls of the stomach along the greater curvature to achieve a tubular reconfiguration and decrease gastric volume, similar to surgical sleeve gastrectomy.[7] Available literature, including prior published reports by our group, suggest an average %TBWL of 15%–20% at 6 months to 2 years after ESG, with almost all patients achieving a minimum of 10% TBWL.[8-10]

Given the relatively recent adoption of ESG by endoscopists, there are a lack of data on its long-term effectiveness beyond 2 years after the procedure. This is an important gap in the current knowledge given the generally high relapse rates observed in virtually all treatments of obesity, and a concern for behavioral and anatomic adaptation and changes over time (eg, overeating leading to suture dehiscence and increased gastric volume) that can lead to regaining initial weight after ESG.[11,12] Here we present our outcome data for up to 5 years after ESG in a large single-center cohort of patients with obesity. This study aims to assess the safety, efficacy, and durability of ESG at 5 years for management of obesity. Additionally, predictors of long-term weight loss are determined.

What You Need to Know?

Background

Endoscopic sleeve gastroplasty is a minimally invasive procedure. Results have been reported for up to two years.

Findings

In this single-center prospective cohort of 216 patients undergoing ESG for treatment of obesity, participants maintained a mean total body weight loss (TBWL) of 15.9% (95%CI 11.7-20.5) at 5 years after the procedure. There was an overall rate of 1.3% for moderate adverse events (AEs), without any severe or fatal AEs.

Implications for patient care

These results show the long-term efficacy and safety of ESG for management of obesity, especially in patients who have suboptimal results with pharmacotherapy, do not qualify for surgical bariatric procedures, or refuse to undergo them.

Methods

The details of the study methods are reported in the Supplementary Methods. This study is a 5-year analysis of a prospectively maintained cohort. All consecutive patients who underwent ESG from August 2013 to August 2019 were prospectively enrolled in our database and were included in this study. This study was approved by the institutional review board at our medical center (IRB Protocol 1510016654) and was registered at clinicaltrials.gov (NCT04494048).

The inclusion criteria for undergoing ESG procedure included body mass index (BMI) of more than 30 kg/m^2, or >27 kg/m^2 with comorbidities, and failure of previous noninvasive weight loss measures including pharmacotherapy to achieve a sustainable TBWL of at least 5%. Patients with a BMI of more than 40 kg/m^2 were included if they refused to undergo bariatric surgery or were deemed to be high-risk surgical candidates. Patients who received prior pharmacotherapy were considered for ESG only if their weight was stable for at least 3 months before ESG or if they were gaining weight while receiving pharmacotherapy.

Anthropomorphic measurements were performed at the baseline before the procedure, and during scheduled follow-up visits at 1, 3, 6, 12, and 24 months after the procedure. Afterwards, patients were encouraged to continue to have a minimum of yearly follow-up visits. Patients who did not complete >70% of their scheduled follow-up visits (including videos and telephone calls) were categorized as noncompliant in contrast to compliant patients who completed their scheduled visits.

All patients were restricted to a full-liquid diet for the first 2 weeks after the procedure, then advanced to a modified bariatric diet for 4 additional weeks as previously described.

Adjunctive Therapy

Antiobesity pharmacotherapy, both Food and Drug Administration–approved and off-label, was offered as adjunctive therapy to patients after ESG if they failed to achieve 5% weight loss by 3 months after the procedure, or if they experienced weight regain at any point after ESG. For patients with weight regain and contraindication for or inadequate response to pharmacotherapy, a repeat ESG was offered. Surgery, Roux-en-Y gastric bypass, or sleeve gastrectomy was offered again during the follow-up to patients with insufficient weight loss who qualified for surgical management as part of the multidisciplinary follow-up clinic.

Outcome Measures

The primary outcome of this study was %TBWL. The final weight that was included for each patient for main analysis was purely from the original procedure, and before any additional supplementary procedures were performed or adjunctive medications added. Secondary outcomes included percent excess body weight loss (% EWL),[13] procedural details, adverse events (AEs), and predictors of weight loss. Patients' weight was measured

during follow-up clinic visits, and was extracted from our institution's electronic medical records. For patients who underwent adjunct therapy after ESG, the last weight before the initiation of adjunct therapy was used in the main analysis. AEs were categorized according to the standard American Society for Gastrointestinal Endoscopy lexicon as mild, moderate, severe, and fatal.

Results

Two hundred and sixteen patients (68% female) underwent ESG and were included in the analysis. Patients had a mean age of 46 ± 13 years, and mean BMI of 39 ± 6 kg/m^2 at baseline (Table 1). Three patients had undergone failed laparoscopic adjustable gastric banding and the bands were removed before ESG. The other 213 patients did not have any prior gastric or bariatric surgery. Thirteen patients (6%) underwent a repeat ESG during follow-up because of weight regain (see Repeat ESG section). Out of 216 patients, 203, 96, and 68 patients had reached the 1-, 3-, and 5-year follow-up time points, respectively. Of these, data were available on 142, 68, and 56 patients, representing a follow-up rate of 70%, 71%, and 82%, respectively.

Primary Outcome

At 1 year mean TBWL was 15.6% (95% confidence interval [CI], 14.1–17.1; $P < .001$) with 89% and 77% of patients achieving 5% and 10% TBWL, respectively (Table 2, Figure 1). At 3 years mean TBWL was 14.9% (95% CI, 12.1–17.7; $P < .001$) and 85% and 63% of patients maintained 5% and 10% TBWL, respectively. At 5 years mean TBWL was 15.9% (95% CI, 11.7–20.5; $P < .001$) and 90% and 61% of patients maintained 5% and 10% TBWL, corresponding to number needed to treat of 1.1 and 1.6, respectively. Patients' TBWL at their nadir weight after ESG had a mean of 16.7% (95% CI, 15.6–17.7) (Table 2). Patients' mean weight gain after nadir was 2.9 kg until the end of the follow-up period (95% CI, 2.3–3.7 kg).

At 1 year mean EWL was 47.9% (95% CI, 42.4–53.3; $P < .001$) with 80% of patients achieving 25% EWL. At 3 years mean EWL was 45.1% (95% CI, 34.9–55.2; $P < .001$) and 68% of patients maintained 25% EWL. At 5 years mean EWL was 45.3% (95% CI, 32.9–57.7; $P < .001$) and 74% of patients maintained 25% EWL. Patients' EWL at their nadir weight after ESG had a mean of 53.5% (95% CI, 49.1–57.9).

Predictors of Weight Loss

In univariable analysis, older age was associated with lower TBWL during follow-up, whereas higher BMI before ESG, higher TBWL at 1 month after ESG, and compliance with scheduled visits were predictors of higher TBWL during follow up (Table 3). In multivariable analysis, older age remained a predictor of lower TBWL during follow-up, whereas higher TBWL at 1 month after ESG and compliance with scheduled visits remained predictors of higher TBWL during follow-up. Endoscopist's experience, as reflected in the case number, was

Table 1. Baseline Characteristics of the Study Population

Patient characteristic	N = 216
Age, mean (SD), *y*	46 (13)
Female, n (%)	146 (68)
BMI, *kg/m^2*, mean (SD)	39 (6)
BMI 30–35, n (%)	68 (32)
BMI 35–40, n (%)	69 (32)
BMI ≥40, n (%)	76 (36)
Diabetes, n (%)	67 (31)
Hemoglobin A_{1c}, %, mean (SD)	5.8 (1.0)
Adjunct pharmacotherapy started before ESG, n (%)	78 (36)
Adjunct pharmacotherapy started after ESG, n (%)	58 (27)
Race, n (%)	
White	87 (41)
Hispanic	34 (16)
Black	18 (9)
Middle Eastern	18 (9)
Other	4 (2)
Declined	51 (24)

BMI, body mass index; ESG, endoscopic sleeve gastroplasty; SD, standard deviation.

Table 2. Percent TBWL During Follow-up

Follow-up, *mo*	TBWL, % (95% CI)	*P* value	TBWL ≥5%, n (%)	TBWL ≥10%, n (%)
1	8.9 (8.5–9.4)	< .0001	177 (88)	73 (36)
3	12.3 (11.5–12.9)	< .0001	171 (93)	129 (70)
6	14.5 (13.4–15.6)	< .0001	142 (92)	120 (77)
12	15.6 (14.1–17.1)	< .0001	118 (89)	103 (77)
24	15.3 (13.4–17.2)	< .0001	87 (85)	74 (72)
36	14.9 (12.1–17.7)	< .0001	50 (85)	37 (63)
48	13.5 (9.6–17.4)	< .0001	26 (79)	22 (67)
60	15.9 (11.7–20.5)	< .0001	28 (90)	19 (61)
Nadir weight	16.7 (15.6–17.7)	< .0001	207 (96)	172 (80)

CI, confidence interval; TBWL, total body weight loss.

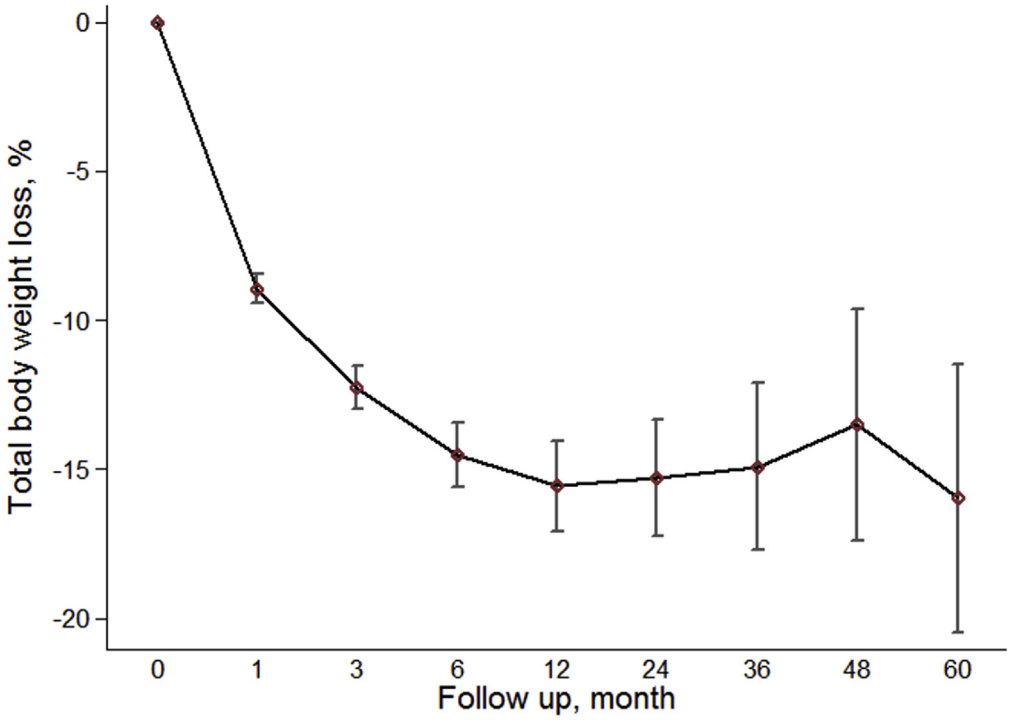

Figure 1. Percent total body weight loss (with 95% CI) after endoscopic sleeve gastroplasty.

also found to be a predictor of TBWL after ESG ($\beta = 8.5$; $P = .002$) (Table 3).

Adjunct Therapy

Pharmacotherapy. Fifty-eight (27%) patients started weight-loss pharmacotherapy after ESG, which was initiated at a median of 5 months after ESG (interquartile range, 3–9 months). Ninety percent of these were patients who had a TBWL of 5% or more at the time of initiating pharmacotherapy but showed weight regain. In univariable and multivariable analysis adjunct pharmacotherapy was not associated with a significant difference in mean TBWL during follow-up compared with patients who did not receive it (Table 3). However, for patients who received adjunct pharmacotherapy, weight stabilized after its initiation as mean %TBWL after starting medication was 12.4% compared with 11.5% just before starting medication, indicating no further weight regain (difference, 0.9%; 95% CI, -0.1% to 1.9%; $P = .076$).

Repeat endoscopic sleeve gastroplasty. Thirteen patients (6%) had a repeat ESG because of weight regain and to ensure weight maintenance at a median of 24 months after their initial ESG (range, 12 to 51 months). These patients had a mean of 2.6 kg weight regain (standard deviation, 4.9 kg, equivalent to mean of 2.3% TBWL) from their nadir weight, and an average TBWL of 21.5% (standard deviation, 11%) before their second ESG, which was stabilized at an average TBWL of 24.2% (difference, 2.6%; $P = .297$) at 1 year after the second ESG.

Bariatric surgery. Two patients (1%) underwent laparoscopic sleeve gastrectomy after their ESG because of inadequate weight loss. A patient with initial BMI of 51 kg/m^2 achieved a TBWL of 15% at 6 months after the procedure, which was deemed to be inadequate and underwent sleeve gastrectomy leading to a 33% TBWL. A second patient with prior failed laparoscopic adjustable gastric banding and an initial BMI of 37 kg/m^2 failed to have any weight loss after ESG and underwent sleeve gastrectomy leading to a 13% TBWL 2 years after the surgery.

Table 3. Regression Analysis of Predictors of TBWL

	Univariable			Multivariable		
	β	SE	*P* value	β	SE	*P* value
Age	-0.1	0.01	.004	-0.4	0.1	.001
Female	-0.4	1.0	.727	-4.5	3.1	.152
Baseline BMI	0.2	0.07	.018	-0.02	0.2	.922
TBWL, % at 1 mo	0.9	0.1	< .001	1.1	0.3	< .001
Case number, quartiles	0.9	1.1	.392	7.3	2.8	.009
Compliance	5.3	0.9	< .001	9.2	2.7	.001
Adjunct pharmacotherapy	-1.6	1.0	.127	3.3	4.4	.448
Number of bites	0.1	0.08	.428	0.03	0.1	.780
Change in stomach length	-0.2	0.3	.539	0.3	0.2	.179

BMI, body mass index; SE, standard error; TBWL, total body weight loss.

Adverse Events

Mild adverse events. Nausea, pain, constipation, and heartburn were common after the procedure. Mild AEs were seen in 32% of patients. Fifty-four patients (25%) experienced heartburn for up to 3 weeks after the procedure, without need for admission or change in care protocol. Forty-three patients (19%) experienced nausea and/or vomiting after the procedure, which was controlled with antiemetic medications or outpatient intravenous hydration without need for overnight admission. Sixty-five patients (31%) experienced epigastric pain beyond 24 hours after the procedure, which was controlled by continuing their initial pain medication regimen without need for admission or repeat endoscopy and resolved within 2 weeks of the procedure. Two patients had prolonged pain that lasted for more than 2 weeks and needed increasing proton pump inhibitor dose, adding sucralfate, and increasing the duration of their liquid diet. Sixty-three patients (29%) experienced constipation, which was controlled with over-the-counter laxatives. There was 1 case of superficial esophageal tear from using the overtube with the Overstitch device, which was controlled endoscopically without need for repeat procedure.

There was 1 case of asymmetric paresthesia that began in association with 55 lb of weight loss after ESG. Extensive metabolic and neurologic work-up showed spinal white-matter plaques and low serum thiamine (vitamin B_1) level. However, the pattern of neurologic findings was not compatible with known thiamine deficiency syndromes and repletion of thiamine to normal levels was not associated with change in neurologic symptoms, and it remains unclear whether the neurologic findings were related to a nutritional deficiency after ESG.

Moderate adverse events. There was total of 3 moderate AEs. These included 1 case of left upper quadrant pain starting 18 months after the procedure with unremarkable computed tomography scan and endoscopy showing the ESG sutures in place with bridging fibrosis bands. Following the patient's request for reversal of the procedure the ESG sutures were cut leading to increased gastric volume and improvement in pain, suggesting that overeating might have been a factor in causing the symptoms. There were 2 cases of perigastric leak, both occurring after dietary indiscretion, which were managed as an inpatient with antibiotics, and percutaneous drainage in 1 case, without need for surgery. There was an overall rate of 1.3% moderate AEs, without any severe or fatal AEs according to American Society for Gastrointestinal Endoscopy definitions.

Discussion

This study demonstrates the safety, efficacy, and durability of ESG for up to 5 years for management of obesity. We found an average TBWL of 15.9% at 5 years after the procedure, with 90% of the patients maintaining a TBWL of 5% or more. Importantly, we were able to show that patients' weight loss evaluated only 1 month after the ESG is an independent predictor of their weight loss throughout the follow-up. We also found that younger patients respond better to ESG and that endoscopist's experience is an important predictor of success. Our analysis suggests that although post-procedural adjunct pharmacotherapy might not induce further weight loss in nonresponders, it is effective in stabilizing their weight and preventing further weight gain.

To the best of our knowledge, this is the first study to demonstrate the long-term efficacy of ESG for up to 5 years after the procedure. Previous studies, including reports from our own group, had shown that ESG is safe and effective for up to 2 years after the procedure. In a previous report on 91 patients who underwent ESG at our center, we reported a TBWL of 21% at 2 years after the procedure.[8] A similar study by Lopez-Nava et al[9] in 2017 reported a TBWL of 18.6% 2 years after ESG. A recent multicenter international study on 193 patients reported a TBWL of 15% at 1 year after the procedure,[10] and a recent meta-analysis of studies published between 2016 and 2019 reported a TBWL of 17.2% (95% CI, 14.6–19.7) at 18–24 months.[14] Compared with these results, we have been able to show for the first time that weight loss after ESG is durable for up to 5 years, with an average TBWL of nearly 16% at the end of the follow-up. Importantly, we were able to show that patients' weight is largely stable from 3–5 years after the procedure, a promising finding regarding long-term effectiveness of ESG even beyond 5 years. It is important to note that 90% of participants maintained a TBWL of 5%, and 74% of patients maintained an EWL of 25% or more at 5 years, qualifying as a primary endoscopic bariatric intervention according to American Society for Gastrointestinal Endoscopy and the American Society for Metabolic and Bariatric Surgery joint task force on Preservation and Incorporation of Valuable endoscopic Innovations.[15] These weight loss results, with a number needed to treat of 1.1 to achieve TBWL of 5% or more at 5 years, are clinically significant according to prior studies showing improvement in obesity-related comorbidities, such as insulin resistance and diabetes, dyslipidemia, and hypertension with TBWL of 5% or more.[16]

In addition to the long-term durability of ESG, our results suggest that ESG is safe, with no severe or fatal AEs in our cohort, consistent with the available literature.[17] Although we encountered only 1 case of thiamine deficiency in our cohort, clinicians should be vigilant about the possibility of nutritional deficiencies after ESG, especially in patients with significant weight loss and decreased intake. Establishing ESG as a safe procedure by following the appropriate endoscopic technique and periprocedural care, as described here, can result in more widespread training and adoption of ESG for management of obesity in communities where patients

are commonly limited in choosing between medical or surgical treatment. In fact, recent publications suggest that ESG remains safe and effective when performed outside of large academic centers.[18] Additionally, although focus should be on lifestyle and behavioral modifications for prevention and early management of obesity among children and adolescents, a recent publication by Alqahtani et al[19] suggests that ESG is also safe and effective when performed in the pediatric population. After considering the previously mentioned body of evidence regarding the short-term safety and efficacy of ESG in various populations and settings, and the durability of its effects reported here, appropriate procedural coding and insurance coverage remain the main issues preventing its widespread use. A multicenter randomized clinical trial of ESG (MERIT trial) is underway in the United States and will help to further refine and clarify the results reported from retrospective and prospective case series and cohorts.

Not all patients respond the same to bariatric procedures including ESG, and prediction of patient response is an important part of patient selection and post-procedural care. In this study, we failed to show that technical parameters, such as number of sutures placed, or the change in the stomach length, are independent predictors of weight loss. Importantly, we were able to show that the amount of weight loss at 1 month after the procedure is an independent predictor of weight loss throughout the follow-up for up to 5 years. This is consistent with prior studies, and provides an opportunity for the management team to identify patients who are at high risk of inadequate response in order to initiate adjunct treatments, including early pharmacotherapy.[9] In our cohort, post-procedural pharmacotherapy in these patients was able to prevent further weight gain, but did not lead to significant additional weight loss. Similarly, we were able to show that repeat ESG, although performed in only 13 patients (6%) in our cohort, is feasible and safe, and effective in preventing further weight regain. We also found that patients' compliance with scheduled follow-up is an important and independent predictor of clinical success, regardless of its causal relationship with weight loss, which is consistent with prior findings in this population.[20] It is important to recognize that obesity is a chronic and multifactorial condition, and patients cannot realistically expect a "one-time" treatment to be successful without a comprehensive and multidisciplinary post-procedural care plan, including nutritional, psychiatric, and endocrinology care. Finally, we found that endoscopist's experience is an independent predictor of clinical success, because weight loss outcomes improved with experience during the study period. In a prior study on learning curve for ESG we have shown that efficiency and mastery in ESG was achieved after 38 and 55 procedures, respectively.[21] These findings are important regarding planning and standardization of ESG training, during a therapeutic or bariatric endoscopy fellowship, and for independent gastroenterologists who would like to add ESG to their practice, to ensure safety and reproducible outcomes.[22]

Our study is limited because of lack of a control group, and although we have a complete follow up rate of 71% and 82% at 3 and 5 years, respectively, there is still potential for differential loss to follow-up to affect the findings. Additionally, our results represent practice at an academic center with a significant experience in bariatric endoscopy where patients are also managed by a dedicated multidisciplinary team and are highly motivated (about 70% self-paying), and therefore our outcomes might not be directly generalizable to other settings. Finally, the effect of adjunct pharmacotherapy was evaluated in patients who were identified as nonresponders after ESG, and although they might represent the real-world outcomes of post-procedural pharmacotherapy as a salvage option, they should be interpreted with caution because of presence of selection bias.

In conclusion, our results suggest that ESG is safe and effective, with durable long-term results for at least up to 5 years after the procedure. With a favorable safety profile, and 90% of patients benefiting from clinically significant weight loss 5 years after ESG, this procedure can and should be considered an established reliable option for treatment of obesity.

Supplementary Material

Note: To access the supplementary material accompanying this article, visit the online version of *Clinical Gastroenterology and Hepatology* at www.cghjournal.org, and at http://doi.org/10.1016/j.cgh.2012.11.00.

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Conflicts of interest

These authors disclose the following: Reem Z. Sharaiha is a Consultant for Boston Scientific, Cook Medical, Lumendi, and Olympus. Katherine Saunders is a Consultant and has equity interests in Intellihealth/BMIQ. Rekha Kumar reports receiving consulting fees from Intellihealth; serving as a speaker for Novo Nordisk and Janssen Pharmaceuticals; and having equity interests in Vivus, Zafgen, and Myos Corporation. Louis J. Aronne reports receiving consulting fees from and serving on advisory boards for Jamieson Laboratories, Pfizer, Novo Nordisk, Eisai, Real Appeal, Janssen, and Gelesis; receiving research funding from Aspire Bariatrics, Allurion, Eisai, AstraZeneca, Gelesis, Janssen, and Novo Nordisk; having equity interests in Intellihealth/BMIQ, ERX, Zafgen, Gelesis, MYOS, and Jamieson Laboratories; and serving on a board of directors for Intellihealth/BMIQ, MYOS, and Jamieson Laboratories. The other authors disclose no conflicts.

Methods

Study Population and Follow-up

This study is a 5-year analysis of a prospectively maintained cohort. All consecutive patients who underwent endoscopic sleeve gastroplasty (ESG) from August 2013 to August 2019 were prospectively enrolled in our database and were included in this study. All procedures were performed in a single center by the same gastroenterologist (RZS). This study was approved by the institutional review board at our medical center (IRB Protocol 1510016654) and was registered at clinicaltrials.gov (NCT04494048).

The inclusion criteria for undergoing ESG procedure included body mass index (BMI) of more than 30 kg/m^2 or >27 kg/m^2 with comorbidities, and failure of previous noninvasive weight loss measures including pharmacotherapy to achieve a sustainable total body weight loss (TBWL) of at least 5%. Patients with a BMI of more than 40 kg/m^2 were included if they refused to undergo bariatric surgery or were deemed to be high-risk surgical candidates. Patients who received prior pharmacotherapy were considered for ESG only if their weight was stable for at least 3 months before ESG or if they were gaining weight while receiving pharmacotherapy. Of note, subgroups of this patient cohort have been described in prior studies[1-3] but with less than 2 years of follow-up.

The exclusion criteria included prior family history of gastric cancer, history of neoplastic gastric lesions, significant mental health disorders as determined by a psychologist, coagulopathy, and any significant comorbidities precluding deep sedation. Before the decision was made to perform ESG, patients were evaluated by a multidisciplinary team including a gastroenterologist, endocrinologist, a nutritionist, and a psychologist as needed.

Anthropomorphic measurements and laboratory studies were performed at the baseline before the procedure, and during scheduled follow-up visits at 1, 3, 6, 12, and 24 months after the procedure. Afterwards, patients were encouraged to continue to have a minimum of yearly follow-up visits. A telephone call or video follow-up was done if patients did not attend their follow-up visits. Patients who did not complete >70% of their scheduled follow-up visits (including videos and telephone calls) were categorized as noncompliant in contrast to compliant patients who completed their scheduled visits. All participants were scheduled to have a follow-up visit with the nutritionist after the procedure and were required to continue with lifestyle and diet interventions according to the recommendations of their provider.

Endoscopic Sleeve Gastroplasty Procedure

Data were recorded on the technical details of the ESG, which was performed in accordance to the previously published procedure.[1] All procedures were performed in an outpatient endoscopy suite, under general anesthesia. The procedures were performed in the left lateral position, or supine if unable to turn patient, using a standard gastroscope (GIF-H190, or GIF-HQ190, Olympus, Center Valley, PA) with carbon dioxide insufflation. After mapping anterior and posterior suture lines from incisura to cardia with argon plasma coagulation, a double-channel gastroscope (GIF-2TH160, GIF-2TH180, Olympus) outfitted with the OverStitch suturing device (Apollo Endosurgery, Austin, TX) was used to perform the procedure. During the initial phase of the study an overtube was used during the suturing; with increased experience overtube use was discontinued. Full-thickness sutures (2–0, nonabsorbable polypropylene) were placed in 2 layers from incisura to cardia to approximate the anterior and posterior walls of stomach and achieve a tubular reconfiguration and decreased gastric volume. The first layer was performed in an either Z or U pattern (with an average of 4 sutures and 6 bites per suture). A second layer was performed in an interrupted or N pattern (with an average of 2 sutures and 4 bites per suture). This second layer served as a reinforcement layer, and to further reduce the volume of the sleeve. All cases received preprocedural prophylactic antibiotic (levofloxacin, 500 mg intravenously), the sleeve was lavaged with 80 mg of topical gentamicin at the end of the procedure, and patients received 3 days of oral antibiotics after the procedure. Antiemetics were used before and after the procedure as described previously.[1] Initially patients were admitted overnight for observation; however, after demonstrating the safety of the ESG procedure in the first 11 patients, the protocol was changed to same day discharge after short observation in the postanesthesia care unit. All patients were restricted to a full-liquid diet for the first 2 weeks after the procedure, then advanced to a modified bariatric diet for 4 additional weeks as previously described.[4] All patients were examined with an upper gastrointestinal (GI) series 1–7 days after their procedure.

Adjunctive Therapy

Antiobesity pharmacotherapy, both Food and Drug Administration–approved and off-label, was offered as adjunctive therapy (phentermine and topiramate alone or in combination, bupropion and naltrexone alone or in combination, lorcaserin, liraglutide, metformin) to patients after ESG as part of their multidisciplinary care and according to their clinical indications and clinical course. Specifically, pharmacotherapy was offered to patients after ESG if they failed to achieve 5% weight loss by 3 months after the procedure, or if they experienced weight regain at any point after ESG. For patients with weight regain and contraindication for or inadequate response to pharmacotherapy, a repeat ESG was offered. Additionally, starting at 1 year after the procedure

patients' anatomy was evaluated with an upper GI series, which was compared with their initial upper GI series performed within 1 week after the ESG. For compliant patients with evidence of suture dehiscence or increased stomach volume a repeat ESG procedure was offered. Surgery, Roux-en-Y gastric bypass, or sleeve gastrectomy was offered again during the follow-up to patients with insufficient weight loss who qualified for surgical management as part of the multidisciplinary follow-up clinic.

Outcome Measures

The primary outcomes of this study were (%TBWL = [(initial weight) – (postoperative weight)] / [(initial weight)] * 100)[5] at 1, 3, and 6 months, and at 1, 2, 3, 4, and 5 years after the procedure. The final weight that was included for each patient for main analysis was purely from the original procedure, and before any additional supplementary procedures were performed or adjunctive medications added. Secondary outcomes included % excess body weight loss (%EWL = [(initial weight) – (postoperative weight)] / [(initial weight – ideal body weight)] * 100; ideal body weight is defined by the weight corresponding to a BMI of 25 kg/m^2),[5] procedural details, adverse events (AEs), and predictors of weight loss, including analysis of the effect of procedural details, patients' compliance, and adjunct pharmacotherapy on weight loss. Patients' weight was measured during follow-up clinic visits, and was extracted from our institution's electronic medical records. For patients who underwent adjunct therapy after ESG, the last weight before the initiation of adjunct therapy was used in the main analysis.

Adverse Events

AEs were categorized according to the standard American Society for Gastrointestinal Endoscopy lexicon as mild, moderate, severe, and fatal.[6] AEs were considered mild when the procedure was aborted because of the event or when there was an unplanned admission of 3 nights or less. Moderate AEs were defined as an unplanned admission of 4–10 nights; intensive care unit admission for 1 night; or when blood transfusion, repeat endoscopy, or interventional radiology procedure was required. Severe AEs were defined as an unplanned admission for more than 10 nights, intensive care unit admission for more than 1 night, or if surgery was required. Fatal AEs was defined as death caused by the event.

Statistical Analysis

Descriptive statistics were reported as means (standard deviation), median (interquartile range), or counts and proportions. Variables were analyzed using paired Student t test, chi-square, and Fisher exact tests in univariate analysis. Logistic and linear regressions were used for univariable and multivariable analysis. Mixed linear models with fixed effect for time since the procedure, and random intercept for individual patients were used to test the linear trend of change in the outcomes after ESG and evaluate the predictors of weight loss in univariable and multivariable models. Standard beta coefficients (β) and standard errors are reported for regressions. All tests are 2-tailed with a significance level of $\alpha = 0.05$. All analyses were performed with Stata version 13.0 for Windows (StataCorp LP, College Station, TX). To evaluate the effect of endoscopist experience on weight loss outcomes, consecutive cases were divided into quartiles based on the date of the procedure to reflect endoscopist's increasing experience over time.

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