Surgery for Obesity and Related Diseases 16 (2020) 340–351

SURGERY FOR OBESITY AND RELATED DISEASES

Original article

Safety and efficacy of endoscopic sleeve gastroplasty worldwide for treatment of obesity: a systematic review and meta-analysis

Shailendra Singh, M.D.[a], Diogo Turiani Hourneaux de Moura, M.Sc., M.D., Ph.D.[b], Ahmad Khan, M.D.[c], Mohammad Bilal, M.D.[d], Michele B. Ryan, M.S.[b], Christopher C. Thompson, M.Sc., M.D., F.A.S.G.E., F.A.C.G., A.G.A.F.[b,*]

[a]*Division of Gastroenterology, West Virginia University Health Sciences Center Charleston Division, Charleston, West Virginia*
[b]*Division of Gastroenterology, Hepatology, and Endoscopy, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts*
[c]*Department of Medicine, West Virginia University Health Sciences Center Charleston Division, Charleston, West Virginia*
[d]*Division of Gastroenterology, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, Massachusetts*

Received 5 August 2019; accepted 2 November 2019

Abstract

Background: Endoscopic sleeve gastroplasty (ESG) has gained momentum as a promising, minimally invasive bariatric therapy worldwide.

Objective: We performed the first comprehensive systematic review and meta-analysis of studies to evaluate the efficacy, safety, and procedural technique of ESG.

Methods: Bibliographic databases were systematically searched for studies assessing patients who underwent ESG for the treatment of obesity. Studies were included if they reported percent total weight loss or percent excess weight loss and the incidence of serious adverse events. Studies with <15 patients, follow-up period <6 months, and overlapping patients were excluded.

Results: Eight observational studies with 1859 patients were included. Pooled mean percent total weight loss at 6, 12, and 24 months was 14.86 (95% confidence interval [CI]: 13.83–15.90), 16.43 (95%CI: 15.23–17.63), and 20.01 (95%CI: 16.92–23.11), respectively. Pooled mean percent excess weight loss at 6, 12, and 24 months was 55.75 (95%CI: 50.61–60.89), 61.84 (95%CI: 54.75–68.93), and 60.40 (95%CI: 48.88–71.92), respectively. The pooled incidence of serious adverse events was 2.26% (95%CI 1.25–4.03) and no mortality was reported. Gastrointestinal bleeding and perigastric fluid collection were the most common reported serious adverse events; however, the pooled incidence of both was <1%. Variations in procedural technique were seen, but the full-thickness nature of suturing was reported in all studies. A layer of reinforcement sutures was performed in the majority of studies (n = 6). Limitations include the lack of controlled studies, long-term follow-up data, and standardization of technique.

Conclusion: ESG, a minimally invasive bariatric therapy, is reproducible among centers worldwide with effective weight loss and favorable safety profile outcomes. Controlled studies would be valuable to further corroborate these findings. (Surg Obes Relat Dis 2020;16:340–351.)

Key words: Obesity; Endoscopic sleeve gastroplasty; ESG; Endoscopic suturing; Gastroplasty; Endoscopic bariatric therapy; EBT; Bariatric endoscopy; Obesity endolumenal surgery; Overstitch; Sleeve gastrectomy

*Correspondence: Christopher C. Thompson, Brigham and Women's Hospital, Division of Gastroenterology, Hepatology, and Endoscopy, 75 Francis St., Thorn 1423, Boston, MA 02115.

E-mail address: cthompson@hms.harvard.edu (C.C. Thompson).

https://doi.org/10.1016/j.soard.2019.11.012

Obesity has become an epidemic worldwide and is associated with significant morbidity and mortality. Worldwide prevalence of obesity has nearly tripled between 1975 and 2016. According to World Health Organizations estimates, in 2016 nearly 2 billion adults (39% of adults) were overweight, and >650 million were obese [1]. Most patients fail to achieve sustained weight loss with lifestyle modification and pharmacotherapy. Bariatric surgery is an effective long-term solution for weight loss in patients with class III and class II with obesity-related co-morbidities. The benefits of bariatric surgery outweigh the risk; however, it is irreversible and carries the risk of complications [2]. Moreover, only <1% to 2 % of eligible patients eventually undergo surgery [3].

Endoscopic bariatric and metabolic therapies (EBMTs) have emerged over the years, intending to fill the gap between medical and surgical therapies to combat the obesity epidemic [4]. Endoscopic sleeve gastroplasty (ESG) is a minimally invasive technique that uses an endoscopic suturing device (OverStitch; Apollo Endosurgery, Austin, TX, USA) to apply full-thickness sutures in the stomach, to reduce gastric capacity and alter gastric motility [5,6]. ESG was first performed using the current full-thickness suturing device in 2012 by Thompson and Hawes [6,7]. Since then, there has been growing interest in ESG, and many studies have demonstrated safety and efficacy of this procedure.

Despite growing interest, most studies evaluating the role of ESG are single center with an overlapping enrollment time. ESG procedure continues to gain popularity and is now being performed worldwide. Previously published systemic reviews and meta-analyses have included a small number of patients and lack the comprehensive global data reported in recent studies. A recent systematic review by Cohen et al. [8] concluded that endoscopic gastroplasty does not have enough quality scientific evidence regarding long-term weight loss and the procedure's safety to recommend the use in current clinical practice. This systemic review had methodic drawbacks and combined ESG with other endoscopic gastroplasty techniques, including plication of the fundus, that use different devices and attempt to exploit different mechanisms of action [9,10]. Several eligible studies were also not included. Another meta-analysis of EBMT included ESG, AspireAssist, and primary obesity surgery endolumenal in a limited number of patients [11].

Hence, we aimed to conduct a systematic review and meta-analysis of available literature in an attempt to evaluate the outcomes specifically for ESG in the treatment of obesity.

Methods

Literature search strategy

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines [12]. Electronic searches were performed by an experienced librarian using MEDLINE (PubMed), Scopus, Cochrane Register of Controlled Trials and Web of Science databases from their dates of inception to June 2019. There was no language restriction; however, we restricted our search query to observational and randomized controlled trials. In addition to original articles, we searched for abstracts and presentations related to bariatric endoscopy presented at major scientific meetings.

The terms used for data search included "Endoscopic sleeve gastroplasty," "ESG," "Gastroplasty," "Endoscopic Bariatric Therapy," "EBT," "Bariatric Endoscopy," "Obesity Endolumenal Surgery," "Overstitch," "Apollo method," and "Endoscopic suturing." We also reviewed the list of references from retrieved articles for identification of potentially relevant studies. All data were extracted from article texts, tables, and figures with any estimates made based on the presented data and figures. Three investigators (S.S., M.B., and A.K.) independently reviewed each included article, and its eligibility was determined based on predetermined inclusion and exclusion criteria. Any discrepancy resolved by discussion and reevaluation by senior authors (C.C.T. and D.T.H.M.).

Selection criteria

All randomized controlled trials and observational studies published or presented as original research or abstracts in a major international meeting in which human patients underwent ESG for obesity treatment were included. Studies were excluded if, endoscopic gastroplasty techniques using devices other than the OverStitch endoscopic suturing system were used. Studies were also excluded if percent total weight loss (%TWL) or percent excess weight loss (% EWL) were not clearly defined and reported, serious adverse events (SAE) were not reported, follow-up period was <6 months, the study had <15 patients because of the bias associated with case reports/small case series and the learning curve associated with the ESG procedure, patients in the study had undergone a prior endoscopic gastroplasty procedure or bariatric surgery or revision endoscopic procedures after bariatric surgery, and overlapping patient cohorts.

Exclusion of duplicate data

Duplication of studies involving the same patient cohort by the same institution with an accumulated number of patients or extended follow-up or report of different outcomes was avoided. Studies were separated based on the author/operator or the institution and the study enrollment period. Studies with the same or overlapping cohort of patients were identified. The most complete and updated studies were selected for each institution/operator for quantitative synthesis. In multicenter studies, data for each operator/institution were separated, and if updated data were available as a part of another study, then that institution's data from the multicenter study were excluded, and the updated data were extracted.

Data extraction and quality assessment

Three investigators used a standardized data collection form to extract the following information: study design, sample size, patient demographic characteristics, body mass index (BMI), co-morbidities, procedure time, suturing patterns, number of sutures, postprocedure complaints, adverse events, mortality, reversal of ESG, weight loss outcomes at follow-up, and remission of co-morbidities.

Primary outcomes of interest were %TWL or %EWL at follow-up periods 6, 12, 18, or 24 months and incidence of SAE. Secondary outcomes included mild and moderate adverse events, remission of patient co-morbidities, and procedure technique. Any missing data in the included studies were supplemented from the previously published studies involving the same cohort of patients. In case of missing data, the authors of the primary studies were contacted.

The quality assessment of the studies was done by 2 independent authors (A.K. and S.S.) using the Newcastle-Ottawa scale for quality assessment and bias assessment of cohort studies. The Newcastle-Ottawa scale is a validated tool to assess reporting bias and accounts the quality of study in 3 areas, selection, comparability, and exposure/outcome. A score >6 was considered as a good quality score. A disagreement on the score was discussed with a third reviewer (D.T.H.M.) and was resolved by consensus.

Statistical analysis

All statistical analysis was conducted using comprehensive meta-analysis software version 3 (Biostat, Englewood, NJ, USA). Mean values for %TWL and %EWL were pooled as weighted means. Incidence of SAE was combined and expressed as pooled incidence. Meta-analyses for all outcomes were presented as forest plots with summary statistical estimates, 95% confidence intervals (CI), and relative weights. The analysis was performed using the Dersimonian-Laird random effects model. A P value $<$ .05 was considered statistically significant. The I^2 statistic was used to estimate heterogeneity across studies, where values of 25%, 50%, and 75% correspond to cutoff points for low, moderate, and high degrees of heterogeneity.

Results

Study selection

The electronic literature search identified a total of 2587 studies with 37 additional records identified through other sources. Fig. 1 shows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram detailing the process of study selection. Eight studies were included in the final analysis [13–20]. Phase II and III study by Kumar et al. [20] were included while phase I study performed to evaluate the safety and technical feasibility was excluded. A 3-center observational study by Lopez-Nava et al. [21] was excluded because updated studies were included from these centers [14–16]. Similarly, many single-center studies were excluded [5,21–28]. Sartoretto et al. [19] included data from 3 centers; other studies from these centers were excluded [29,30]. Data for outcomes of co-morbidities for Saumoy et al. [14] was supplemented from the study by Sharaiha et al. [25] involving the same cohort of patients because it was missing from the included study.

Risk of bias

The risk of bias between studies was evaluated with Modified New Castle Ottawa, as shown in Appendix 1. All articles were considered adequate for analysis in our study given scores of ≥5.

Study and population characteristics

No controlled or randomized studies were identified. All 8 included studies were observational studies [13–20]. Three studies were multicenter while the other 5 studies were single-center experiences. Majority of the centers were from the United States (n = 5), while the remaining population was from Spain (n = 3), Saudi Arabia (n = 1), Brazil (n = 1), Australia (n = 1), and Dominican Republic (n = 1).

The total number of patients in all studies was 1859. The weighted mean age was 42 years (95%CI: 39.64–44.39) and 17.8% (332) were males. Weighted mean BMI before ESG was 35.8 kg/m^2 (95%CI: 34.78–36.98). Tables 1 and 2 summarize the individual study designs and population characteristics of the included studies.

Primary outcomes

Weight loss

Weight loss outcomes for individual studies are summarized in Table 2. Seven studies reported %TWL with various lengths of follow-up. Pooled mean %TWL at 6, 12, 18, and 24 months was 14.86 (95%CI: 13.83–15.90, I^2 = 93%, 7 studies), 16.43 (95%CI: 15.23–17.63, I^2 = 88%, 6 studies), 16.81 (95%CI: = 13.02–20.59, I^2 = 86%, 2 studies), and 20.01 (95%CI = 16.92–23.11, I^2 = 0%, 2 studies), respectively (Table 3 and Fig. 2a).

Six studies reported %EWL with various lengths of follow-up. Pooled mean %EWL at 6, 12, 18, and 24 months was 55.75 (95%CI: 50.61–60.89, I^2 = 82%, 6 studies), 61.84 (95%CI: 54.75–68.93, I^2 = 69%, 5 studies), 66.87 (95%CI: 50.14–83.60, I^2 = 69%, 3 studies), and 60.40 (95%CI: 48.88–71.92, I^2 = 0%), respectively (Table 3 and Fig. 2b).

Serious adverse events

SAE for individual studies are listed in Table 2. All 8 studies reported the incidence of SAE. The overall pooled incidence of SAE was 2.26% (95%CI: 1.25–4.03, I^2 = 47%)

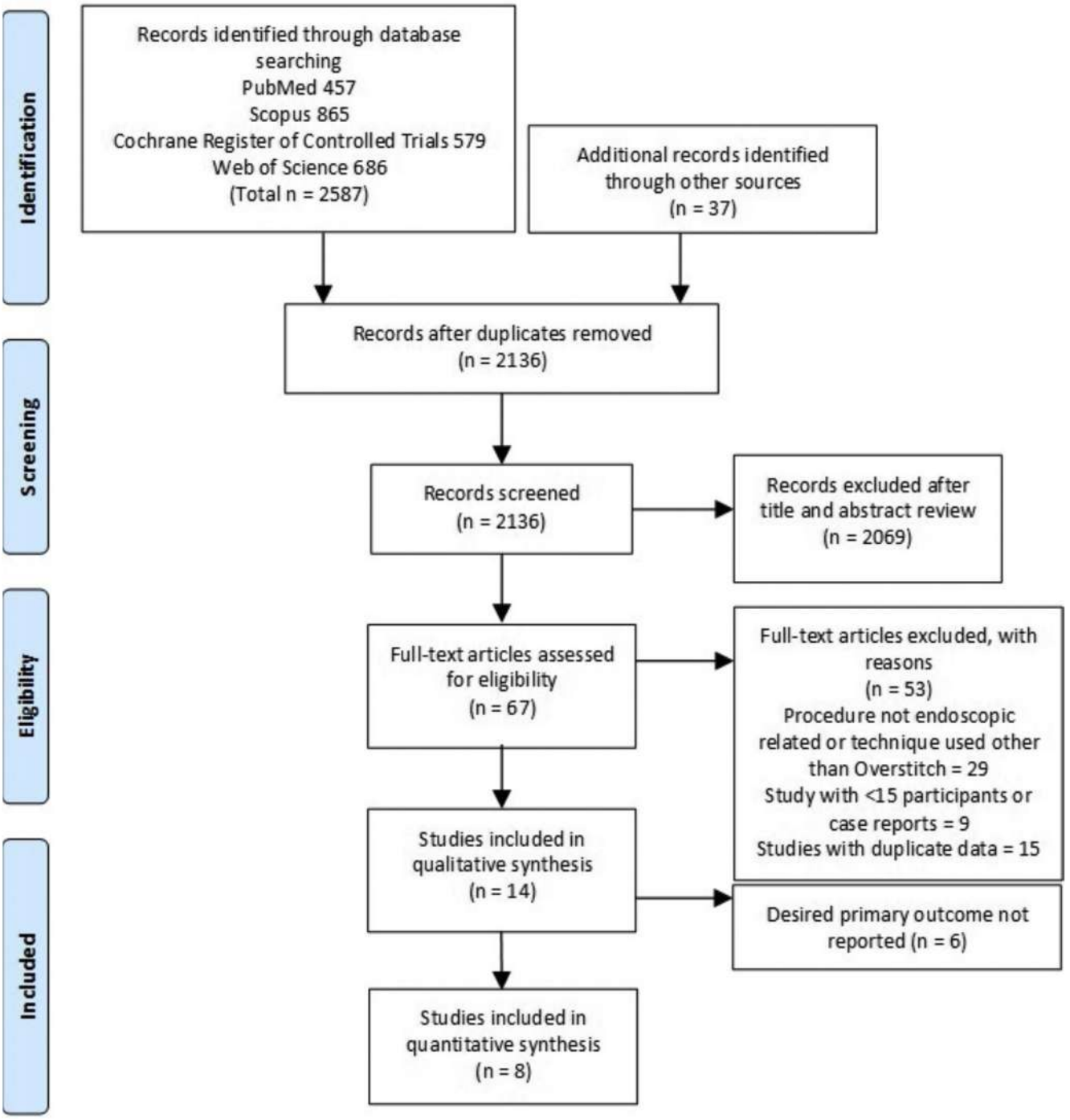

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram of the search strategy and study selection.

(Fig. 3). The pooled incidence of gastrointestinal (GI) bleeding was .82% (95%CI: .49–1.38) and was reported in 4 studies. In all studies, GI bleeding was managed conservatively with observation with or without 1 to 2 units of packed red blood cells transfusion. Emergent esophagogastroduodenoscopy was reported in 1 patient with GI bleeding showed linear ulcerations in the proximal body at the suture line [19]. Perigastric fluid collection was seen in 9 patients (5 studies) with a pooled incidence of .68% (95%CI: .37–1.24). Of these, 2 patients were managed with observation without a need for drainage, 5 patients required percutaneous drainage, and 2 patients underwent surgical intervention. Pooled incidence of perforation was .54% (95%CI: .22–1.34, 2 studies). Perforation was reported in 2 patients,

Table 1
Study designs, inclusion, and exclusion criteria of the included studies

Study (yr published)	Design	Setting	Country	n	Inclusion criteria	Exclusion criteria
Saumoy et al. [14] (2018)	Observational	Single center	United States	128	BMI >30 kg/m^2 with failed noninvasive weight loss measures OR BMI >40 kg/m^2 AND nonsurgical candidates or declined surgery	History of gastric lesions, neoplastic changes or gastric cancer, contraindications, or at high risk to undergo general anesthesia
Alqahtani et al. [13] (2019)	Observational	Single center	Saudi Arabia	1000	BMI >40 or 35 kg/m^2 with co-morbidities	Bleeding disorders, large hiatal hernia, and active peptic ulcer disease
Abu Dayyeh et al. [15] (2017)	Observational	Single center	Unites States	25	BMI between 30 and 40 kg/m^2 with stable weight for 3 mo	Anticoagulation, previous gastric surgery, gastric ulceration, hiatal hernia ≥5 cm, or pregnancy
Lopez-Nava et al. [16] (2017)	Observational	Single center	Spain	154	BMI >30 kg/m^2 who committed for 1-yr multidisciplinary follow-up	Acute, potentially bleeding gastric mucosal lesions (ulcers, acute gastritis), neoplastic lesions, hiatus hernia >3 cm, coagulopathy, and psychiatric disorders
Graus Morales et al. [17] (2018)	Observational	Single center	Spain	148	BMI >30 to <40 kg/m^2	Potentially bleeding lesions, such as ulcers or erosive duodenitis, and preneoplastic or neoplastic findings, contraindications, or at high risk to undergo general anesthesia
Barrichello et al. [18] (2019)	Observational	Multicenter	Brazil (6 centers) Unites States (1 center)	193	Overweight or obese patients who failed diet and lifestyle modifications	Previous gastric surgery, anticoagulation, acute gastric ulceration, cancer, hiatal hernia >5 cm, gastroesophageal motility disorder, and pregnancy
Sartoretto et al. [19] (2018)	Observational	Multicenter	Australia Unites States center 1 Unites States center 2	51 42 19	BMI >27 kg/m^2 and failed multiple diet and lifestyle modifications	Personal or family history of gastric cancer, active gastric ulcers, presence of any gastric condition, which required endoscopic surveillance (e.g., known gastric intestinal metaplasia), known vascular abnormalities, decompensated organ failure, obligate therapeutic anticoagulation, pregnancy/lactation
Kumar et al. [20] (2018)	Observational	Multicenter	Phase II Dominican Republic, Unites States Phase III Dominican Republic, Spain, United States	22 77	BMI >30 kg/m^2 with unsuccessful diet and lifestyle modifications	Bleeding disorders, gastrointestinal disease, prior gastric surgery, active use of weight loss medication, eating disorders, or uncontrolled or severe psychiatric disease

BMI = body mass index.

Table 2
Population characteristics and outcomes of the included studies

Study (yr published)	n	Males n (%)	Age, yr mean (SD)	Pre-ESG BMI, kg/m^2 mean (SD)	Follow-up, mo	% TWL mean (SD)	% EWL mean (SD)	SAE n (%)
Saumoy et al. [14] (2018)	128	42 (32.8)	43.6 (11.3)	38.92 (6.95)	6	13.43 (7.4)	NA	2 (1.5)
					12	15.8 (9.5)	NA	(1 perigastric leak, 1 perforation)
Alqahtani et al. [13] (2019)	1000	103 (10.3)	34.4 (9.5)	33.3 (4.5)	6	13.7 (6.8)	64.3 (56.2)	24 (2.4)
					12	15.0 (7.7)	67.5 (52.3)	(8 severe abdominal pain, 7 postprocedure bleeding, 4 perigastric collections with pleural effusion, 5 postprocedure fever with no sequelae)
					18	14.8 (8.5)	64.7 (55.4)	
Abu Dayyeh et al. [15] (2017)	25	4 (16)	47.6 (10)	35.5 (2.6)	6	NA	54 (40)	3 (12)
					12	NA	54 (40)	(1 perigastric fluid collection, 1 pulmonary embolism, 1 pneumoperitoneum pneumothorax)
					20	NA	45 (41)	
Lopez-Nava et al. [16] (2017)	154	46 (30)	44.9 (9.5)	38.3 (5.5)	6	15.8 (7.1)	47.8 (29.4)	0
					12	18.2 (10.1)	52.6 (31.3)	(no SAE)
					24	19.5 (10.5)	60.4 (31.1)	
Graus Morales et al. [17] (2018)	148	27 (18.2)	41.53 (10)	35.11 (5.5)	6	15.45 (5.9)	64.93 (51)	1 (.67)
					12	17.53 (7.57)	75.4 (85.0)	mild GI bleeding
					18	18.66 (7.3)	79.25 (43)	
Barrichello et al. [18] (2019)	193	45 (23.3)	42.3 (9.6)	34.11 (2.97)	6	14.25 (5.26)	56.15 (22.93)	4 (2.07)
					12	15.06 (5.22)	59.41 (25.69)	(2 GI bleeding, 2 perigastric fluid collections)
Sartoretto et al. [19] (2018)	51 (Australia)	15 (29.4)	43 (11.9)	36.7 (4.9)	6	14.0 (5.6)	49.2 (23.2)	3 (2.6)
	42 (U.S. center 1)	17 (40.5)	49.2 (11.4)	41.2 (8.0)	6	16.3 (7.9)	46.9 (20.3)	(2 GI bleeding, 1 perigastric fluid collection)
	19 (U.S. center 2)	3 (15.8)	41.2 (8.0)	33.6 (4.0)	6	17.7 (1.7)	72.1 (9.7)	
Kumar et al. [20] (2018)	22	2 (9.1)	39.2 (1.6)	34.3 (1.0)	6	17.3 (1.7)	NA	0
					12	17.3 (2.6)	NA	(no SAE)
	77	18 (23.4)	41.3 ± 1.1	36.1 (.6)	6	16.0 (.8)	NA	0
					12	17.4 (1.2)	NA	(no SAE)

BMI = body mass index; ESG = endoscopic sleeve gastroplasty; %TWL = percent total weight loss; %EWL = percent excess weight loss; SAE = serious adverse event; NA = data was not available; GI = gastrointestinal.

Table 3
Pooled percent total weight loss (%TWL) and percent excess weight loss (%EWL)

Follow-up	Outcome	Studies	Total patients	% (95%CI)
6 mo	%TWL	7	1074	14.86 (13.83–15.90)
	%EWL	6	926	55.75 (50.61–60.89)
12 mo	%TWL	6	673	16.43 (15.23–17.63)
	%EWL	5	559	61.84 (54.75–68.93)
18 mo	%TWL	2	126	16.81 (13.02–20.59)
	% EWL	3	134	66.87 (50.14–83.60)
24 mo	%TWL	2	36	20.01 (16.92–23.11)
	%EWL	1	28	60.40 (48.88–71.92)

CI = confidence interval.

1 patient developed pneumoperitoneum and pneumothorax requiring chest tube placement, and the other patient underwent surgical washout. Severe abdominal pain was reported in 8 patients in 1 study with a pooled incidence of .68% (95%CI: .38–1.20) [13]. Postprocedure fever with no sequelae was also reported in 1 study in 5 patients (pooled incidence .48% (95%CI: .25–.95) [13]. Pulmonary embolism was reported in 1 patient (pooled incidence .48%, 95%CI .19–1.25) [15]. In 1 study, only 3 (.003%) patients required reversal of ESG due to persistent symptoms [13]. No mortality associated with ESG was reported in the included studies. The detailed SAE analysis is summarized in Table 4.

Secondary outcomes

Mild-to-moderate postprocedure symptoms

Mild or moderate postprocedure symptoms were not uniformly reported. The majority of patients in all included studies reported abdominal pain or nausea that was controlled with medications. Barrichello et al. [18] reported mild symptoms of nausea, emesis, and abdominal pain in >50% of patients on the first day. These symptoms significantly improved between the first and third day and eventually subsided after 1 week. Saumoy et al. [14] reported 31.2% of patients had postprocedure nausea and 24.2% had mild-to-moderate postprocedure abdominal pain, which lasted <48 hours and was managed with antiemetics and liquid acetaminophen [14]. Whereas, Alqahtani et al. [13] reported abdominal pain or nausea controlled with medications during the first 5 days after surgery in 92.4% of patients.

Co-morbidities

Most studies did not report the outcomes related to co-morbidities; 2 studies analyzed co-morbidities after ESG. One study reported complete remission in type 2 diabetes by the third month after the procedure in 76.5% (n = 13) of the patients, while all the remaining patients showed improvement. All patients with hypertension (n = 28) and 56.3% (n = 18) of patients with dyslipidemia were in complete remission at the last follow-up [13]. Other study reported significant reductions in levels of hemoglobin A1C (6.1 ± 1.1 versus 5.5 ± .4), systolic blood pressure (129.0 ± 13.4 versus 122.2 ± 11.69 mm Hg, $P = .02$), triglycerides (131.84 ± 83.19 versus 92.36 ± 39.43 mmol/dL, $P = .02$), and alanine transaminase (42.4 versus 22 U/L in men, $P = .05$, and 28 versus 20 in women, $P = .01$) at 12 months after ESG compared with baseline [25].

Procedure technique, suture pattern, number of sutures, and procedure time

ESG procedure technique was not uniformly reported in all studies. ESG in all included studies was performed under general anesthesia, and an esophageal overtube was used. ESG in all studies was performed using Apollo OverStitch device (Apollo Endosurgery, Austin, TX, USA) mounted on a double-channel gastroscope (GIF2 T160 or 180 series; Olympus Optical, Tokyo, Japan) with the use a tissue helix and carbon dioxide insufflation. Mapping of the stomach anterior, greater curvature, and posterior surfaces for suture placement sites by using argon plasma coagulation were reported in most studies (n = 5) [14–16,19,20]. Full-thickness nature of the suturing was reported in all included studies. Different patterns of suturing were reported as interrupted "Z" pattern in 3 studies [14,17,19], triangular pattern in 4 studies [13,15,16,19], "U" pattern in 1 study [18], and only interrupted suturing in 1 study [20]. A layer of reinforcement sutures was also reported in the majority of studies (n = 6) [13–16,19,20]. The number of sutures used was not uniformly reported in all studies. The pooled mean number of sutures used per patient based on 4 studies [13–15,19] was 7.87 (95%CI: 5.52–10.21). Other studies reported 4 [17], 4 to 6 [18], 6 to 8 [16], and 9 sutures per patient [20]. One study reported a median of 3 (range, 2–9) sutures for the reinforcement layer [14]. Three studies reported the mean procedure time [13–15]; pooled mean procedure time was 80.48 minutes (95%CI: 51.71–109.262). One other study reported that the majority of the procedures were completed in 45 to 60 minutes [17].

Discussion

In this study, we performed the first comprehensive systematic review and meta-analysis of all available literature worldwide to assess the effectiveness and safety of ESG in >1800 patients. Our analysis shows that ESG is safe and effective in the treatment of obesity.

We found that the pooled mean %TWL at 6, 12, and 24 months was 14.86, 16.43, and 20.01, respectively. Similarly, %EWL at 6, 12, and 24 months was 55.75, 61.84, and 60.40. The pooled incidence of SAE was 2.26%, and no mortality associated with ESG was reported.

A joint task force organized by the American Society for Gastrointestinal Endoscopy and American Society for Metabolic and Bariatric Surgery has previously defined

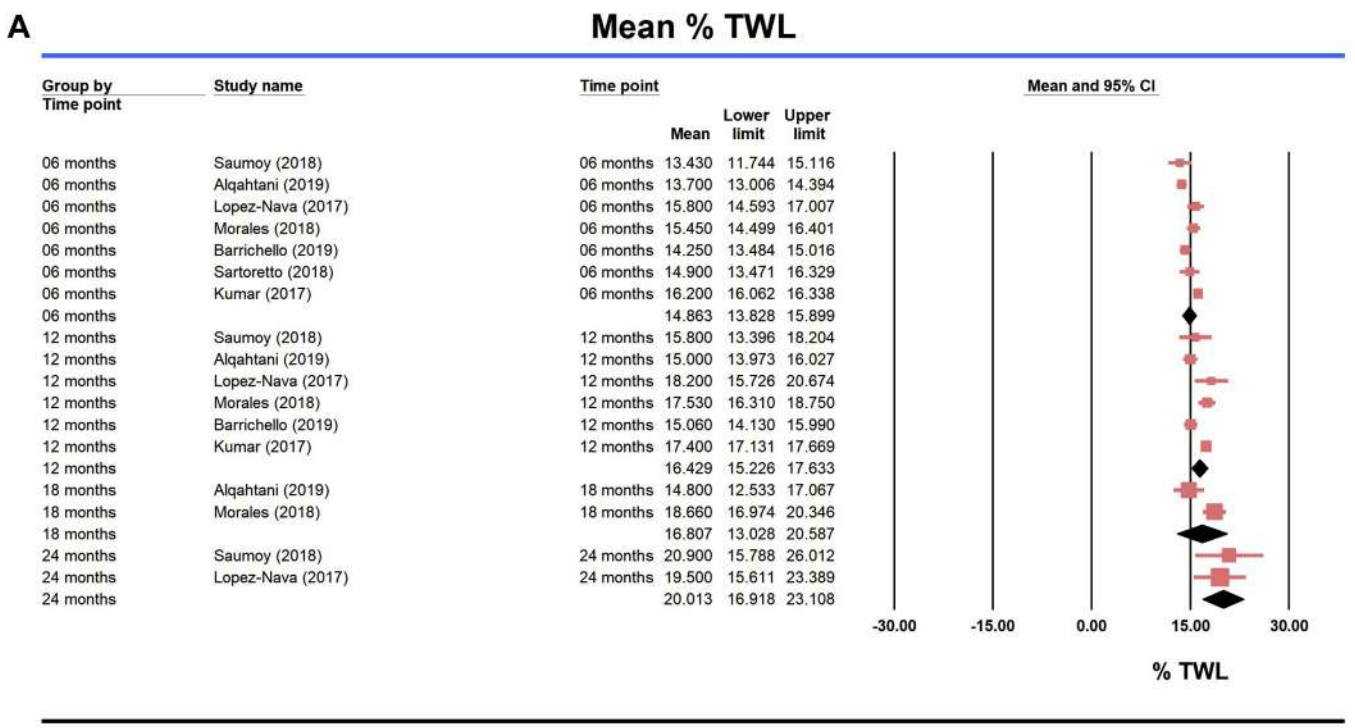

Fig. 2. (a) Forest plots showing percent total weight loss achieved with endoscopic sleeve gastroplasty. (b) Forest plots showing %EWL achieved with endoscopic sleeve gastroplasty. %TWL = percent total weight loss; %EWL = percent excess weight loss; CI = confidence interval.

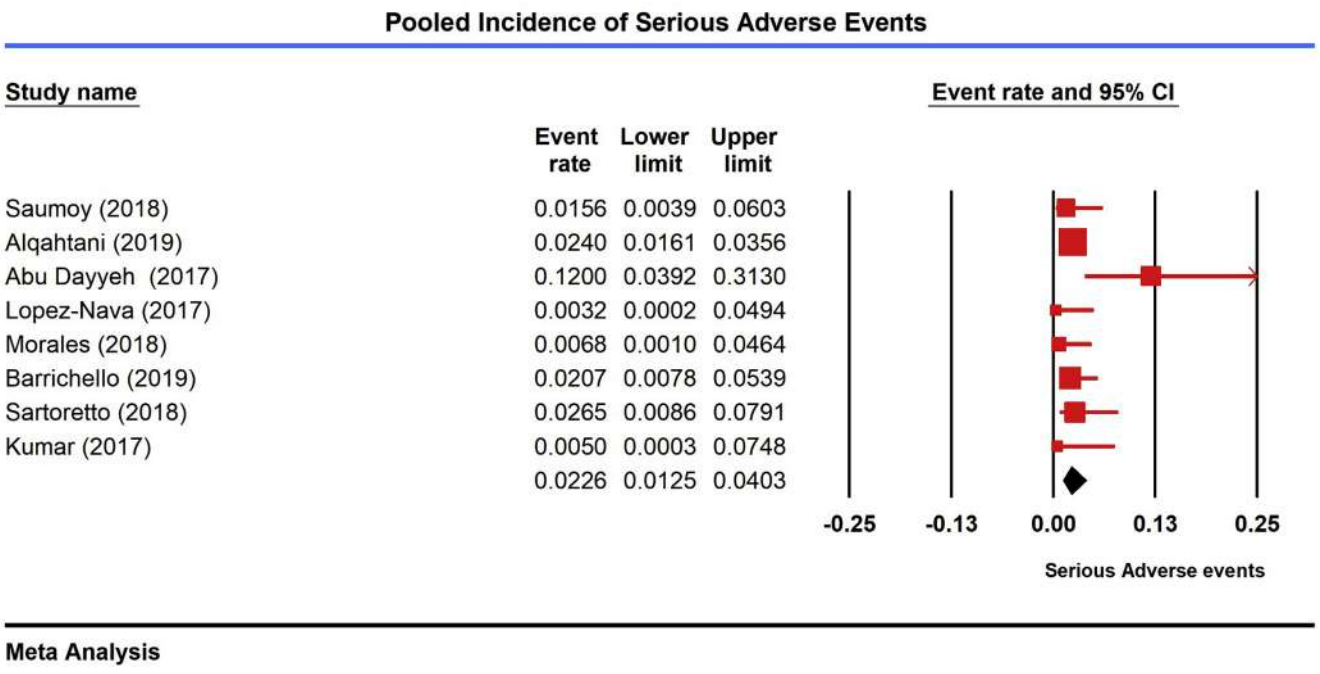

Fig. 3. Forest plot evaluating the pooled incidence of serious adverse events. CI = confidence interval.

thresholds regarding safety and efficacy for EBMT [31]. The task force recommended a minimum of 25 %EWL at 12 months for primary obesity therapies and SAE ≤5% for all EBT. The outcomes for ESG surpasses these thresholds and meets these criteria to be incorporated into clinical practice after adequate training as per the task force recommendations. Although the majority of studies were from centers in the United States and Spain, studies from centers across the world from Saudi Arabia, Brazil, Australia, and the Dominican Republic were also included. Most studies included patients with a BMI >30 kg/m^2, and the weighted mean BMI before the procedure was 35.8. Effective weight loss outcomes were seen in all studies from centers worldwide in this lower BMI obesity group (30–40 kg/m^2).

SAE profile was very favorable; the overall incidence of SAE was only 2.26%. GI bleeding and perigastric fluid collection were the most commonly reported SAE, but the incidence of both was <1%. GI bleeding in all cases was managed conservatively with or without blood transfusions. Perigastric fluid collections were successfully managed with a percutaneous drain in most cases. In the largest included study, only .003% of patients required reversal of ESG due to persistent symptoms [13]. Included studies reported these events as SAE, but a standardized nomenclature and definitions for SAE were lacking. According to American Society for Gastrointestinal Endoscopy Quality Task Force recommendations, most of these reported SAEs can be classified as mild-to-moderate adverse events [32].

According to the American Society for Metabolic and Bariatric Surgery, laparoscopic sleeve gastrectomy (LSG) is the most common bariatric surgical procedure performed [33]. ESG technique similarly focuses on the greater curvature of the stomach; however, there are several differences [30]. In contrast to LSG, ESG requires no abdominal

Table 4
Serious adverse events described in included 8 studies (n = 1859)

Event	No. of occurrences	Occurrence in No. of studies	Pooled incidence (95%CI)
Gastrointestinal bleeding	12	4	.82% (.49–1.38)
Perigastric fluid collection	9	5	.68% (.37–1.24)
Perforation, pneumoperitoneum, or pneumothorax	2	2	.54% (.22–1.34)
Severe abdominal pain	8	1	.68% (.38–1.20)
Postprocedure fever	5	1	.48% (.25–.95)
Pulmonary embolism	1	1	.48% (.19–1.25)
Overall	37	8	2.26% (1.25–4.03)

CI = confidence interval.

incisions, does not require an operating room, and is reversible in some cases. ESG produces remodeling, but the stomach remains intact with its innervation, and blood supply with potential for repeatability, and conversion to bariatric surgery if necessary [34]. LSG and other bariatric surgeries are associated with substantial and durable weight loss [29,35]; meanwhile, long-term data with ESG are still not available in the published literature. In a short-term, follow-up study of matched cohorts, ESG achieved lower weight loss (17.1%TWL) than LSG (23.6%TWL) at 6 months, but the ESG patients had significantly lower adverse events [29]. Gastroesophageal reflux disease is also a common and distressing problem reported in patients after LSG with a frequency as high as 47% [36]. There is considerable overlap in patients eligible for ESG and bariatric surgery. ESG studies included patients who do not otherwise qualify for bariatric surgery or are nonsurgical candidates, thus bridging the gap.

Intragastric balloons (IGB) a space-occupying device is the most common and well-established EBMT. A systematic review and meta-analysis reported 13.2%TWL with IGB at 6 months [37], while a recent review reported 9.7%TWL at 6 months [38]. One of the limitations of IGB therapy is the weight recidivism after removal of the balloon at the end of 6 months [38–40]. In our analysis of ESG studies, %TWL of 14.9 at 6 months was comparable to IGB, but ESG patients did not regain weight at 12 (% TWL 16.8) or 24 months (%TWL 20.0). In 1 recent report, the incidence of SAE associated with IGB was higher than the SAE for ESG in our analysis [40]. ESG seems to provide durable weight loss with less adverse events compared with an IGB up to a follow-up of 2 years.

Studies in our analysis demonstrated effective but small variability in weight loss outcomes, ranging from 15.0% to 18.2%TWL and 52.6% to 75.4%EWL at 12-month follow-up. The reason for the small variability is perhaps related to the difference in patient characteristics, postprocedure diet, concomitant weight loss medication, the intensity of lifestyle modification, and procedure technique. Full-thickness suturing of the gastric greater curvature was reported in all studies, but there were variations in procedure technique. The different patterns of suturing were reported as "Z," "U," and triangular patterns. The number of sutures used was highly variable, but the layer of reinforcement sutures was reported in the majority of studies. Currently, there is not enough evidence regarding the optimal number of sutures or the suture pattern. Use of a few sutures is cost-effective and reduces procedure time but can limit the efficacy of the procedure. We believe full-thickness suture bites and a layer of reinforcement sutures are likely associated with better efficacy, but further studies are needed.

As more physicians gain proficiency with the procedure, we expect a widespread expansion of ESG; however, several areas need to be addressed [41]. Training in this subspecialized area is sparse, standardized training and credentialing methods are required. Identifying the right patient phenotype and physiology will be essential for optimizing outcomes. Further research and development in device design and technology are underway to simplify the procedure for broader dissemination. Concomitant pharmacotherapy with ESG will need to be evaluated to promote durable weight loss. ESG combined with other EBMT, especially small bowel endoscopic procedures either applied simultaneously or sequentially, has the potential to produce the same efficacy as bariatric surgery with beneficial adverse event profile. Finally, ESG is mostly a self-pay procedure in the United States, with coding and insurance coverage remaining significant barriers to widespread adoption.

Ours is the first comprehensive systematic review and meta-analysis to evaluate the cumulative efficacy, safety, and procedural technique, specifically for ESG and from an international perspective. In contrast to prior studies, this analysis follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines to better define outcomes after ESG. Updated studies from many centers with an overall large number of patients were included. A recently published meta-analysis by Li et al. [42] included overlapping patient from a single operator in 2 studies [19,29]. We meticulously examined all studies and avoided overlapping of patient cohorts and duplication of data. A recent multicenter study by Barrichello et al. [18] included in our analysis has not been included in any previous analysis.

Despite our rigorous inclusion criteria, our study has several limitations. The quality of the included studies limits the quality of our systematic review and meta-analysis. None of the included studies were randomized controlled trials; all were observational studies of variable sample size. Length of follow-up, outcome measures, and procedural techniques all slightly varied between studies and considerable heterogeneity was seen in a few of our estimates. Most of the included studies did not clarify about concomitant weight loss medications during follow-up. Although the overall number of patients was relatively large (1859 patients), the number of patients available for analysis for each outcome was less. There is a paucity of controlled data and evidence regarding the impact of ESG on obesity-related co-morbidities. Lack of standardized definition for SAE in included studies also affects the comparison. ESG has only recently gained momentum as a promising technique that naturally limits the availability of long-term follow-up data.

Conclusion

In conclusion, ESG is a minimally invasive bariatric therapy that is reproducible among centers worldwide with effective weight loss outcomes and a favorable safety profile in light of the American Society for Gastrointestinal Endoscopy/American Society for Metabolic and Bariatric Surgery threshold.

Acknowledgments

The authors acknowledge Anna Crawford (Librarian, West Virginia University Health Sciences Library) for conducting the literature searches.

Disclosures

S.S., D.T.H.M., A.K., M.B., M.B.R. have nothing to disclose. C.C.T. is a consultant for Apollo Endosurgery, USGI medical, Fractyl, Boston Scientific, Medtronic, Olympus, and GI dynamics.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.1016/j.soard.2019.11.012.

References

[1] Overweight and obesity [homepage on the Internet]. Geneva: World Health Organization; c2019 [updated 2018 Feb 16; cited 2019 Jun 26]. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

[2] Longitudinal Assessment of Bariatric Surgery (LABS) Consortium, Flum DR, Belle SH, et al. Perioperative safety in the longitudinal assessment of bariatric surgery. N Engl J Med 2009;361(5):445–54.

[3] Buchwald H, Oien DM. Metabolic/bariatric surgery worldwide 2011. Obes Surg 2013;23(4):427–36.

[4] Moura D, Oliveira J, De Moura EG, et al. Effectiveness of intragastric balloon for obesity: a systematic review and meta-analysis based on randomized control trials. Surg Obes Relat Dis 2016;12(2):420–9.

[5] Lopez-Nava G, Galvao MP, Bautista-Castano I, Jimenez-Banos A, Fernandez-Corbelle JP. Endoscopic sleeve gastroplasty: how I do it? Obes Surg 2015;25(8):1534–8.

[6] Kumar N, Lopez-Nava G, Sahdala HNP, et al. 934 Endoscopic sleeve gastroplasty: multicenter weight loss results. Gastroenterology 2015;148(4 Suppl 1):S179.

[7] Neto MG, Zundel N, Campos JM, et al. Endoluminal greater curvature plication – a case series [monograph on the Internet]. Los Angeles: Society of American Gastrointestinal and Endoscopic Surgeons; 2013 [cited 2013]. Available from: https://www.sages.org/meetings/annual-meeting/abstracts-archive/endoluminal-greater-curvature-plication-a-case-series/.

[8] Cohen RV, Oliveira da Costa MV, Charry L, Heins E. Endoscopic gastroplasty to treat medically uncontrolled obesity needs more quality data: a systematic review. Surg Obes Relat Dis 2019;15(7):1219–24.

[9] Edmundowicz SA, Thompson CC. Endoscopic gastroplasty letter: ASGE/ABE. Surg Obes Relat Dis 2019;15(11):2004–5.

[10] Abu Dayyeh BK, Neto MG, Lopez-Nava G, Sharaiha RZ, Kumbhari V, Wilson EB. Endoscopic sleeve gastroplasty is safe and effective: pitfalls of a flawed systematic review. Surg Obes Relat Dis 2019;15(8):1423–4.

[11] Khan Z, Khan MA, Hajifathalian K, et al. Efficacy of endoscopic interventions for the management of obesity: a meta-analysis to compare endoscopic sleeve gastroplasty, aspireassist, and primary obesity surgery endolumenal. Obes Surg 2019;29(9):2287–98.

[12] Moher D, Liberati A, Tetzlaff J, Altman DG, for the PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 2009;6(7):e1000097.

[13] Alqahtani A, Al-Darwish A, Mahmoud AE, Alqahtani YA, Elahmedi M. Short-term outcomes of endoscopic sleeve gastroplasty in 1000 consecutive patients. Gastrointest Endosc 2019;89(6):1132–8.

[14] Saumoy M, Schneider Y, Zhou XK, et al. A single-operator learning curve analysis for the endoscopic sleeve gastroplasty. Gastrointest Endosc 2018;87(2):442–7.

[15] Abu Dayyeh BK, Acosta A, Camilleri M, et al. Endoscopic sleeve gastroplasty alters gastric physiology and induces loss of body weight in obese individuals. Clin Gastroenterol Hepatol 2017;15(1):37–43.e1.

[16] Lopez-Nava G, Galvao MP, Bautista-Castano I, Fernandez-Corbelle JP, Trell M, Lopez N. Endoscopic sleeve gastroplasty for obesity treatment: two years of experience. Arq Bras Cir Dig 2017;30(1):18–20.

[17] Graus Morales J, Crespo Perez L, Marques A, et al. Modified endoscopic gastroplasty for the treatment of obesity. Surg Endosc 2018;32(9):3936–42.

[18] Barrichello S Jr, Hourneaux de Moura DT, Hourneaux de Moura EG, et al. Endoscopic sleeve gastroplasty in the management of overweight and obesity: an international multicenter study. Gastrointest Endosc 2019;90(5):770–80.

[19] Sartoretto A, Sui Z, Hill C, et al. Endoscopic sleeve gastroplasty (ESG) is a reproducible and effective endoscopic bariatric therapy suitable for widespread clinical adoption: a large, international multicenter study. Obes Surg 2018;28(7):1812–21.

[20] Kumar N, Abu Dayyeh BK, Lopez-Nava Breviere G, et al. Endoscopic sutured gastroplasty: procedure evolution from first-in-man cases through current technique. Surg Endosc 2018;32(4):2159–64.

[21] Lopez-Nava G, Sharaiha RZ, Vargas EJ, et al. Endoscopic sleeve gastroplasty for obesity: a multicenter study of 248 patients with 24 months follow-up. Obes Surg 2017;27(10):2649–55.

[22] Lopez-Nava Breviere G, Bautista-Castano I, Fernandez-Corbelle JP, Trell M. Endoscopic sleeve gastroplasty (the Apollo method): a new approach to obesity management. Rev Esp Enferm Dig 2016;108(4):201–6.

[23] Lopez-Nava G, Galvao M, Bautista-Castano I, Fernandez-Corbelle JP, Trell M. Endoscopic sleeve gastroplasty with 1-year follow-up: factors predictive of success. Endosc Int Open 2016;4(2):E222–7.

[24] Lopez-Nava G, Galvao MP, da Bautista-Castano I, Jimenez A, De Grado T, Fernandez-Corbelle JP. Endoscopic sleeve gastroplasty for the treatment of obesity. Endoscopy 2015;47(5):449–52.

[25] Sharaiha RZ, Kumta NA, Saumoy M, et al. Endoscopic sleeve gastroplasty significantly reduces body mass index and metabolic complications in obese patients. Clin Gastroenterol Hepatol 2017;15(4):504–10.

[26] Novikov AA, Afaneh C, Saumoy M, et al. Endoscopic sleeve gastroplasty, laparoscopic sleeve gastrectomy, and laparoscopic band for weight loss: how do they compare? J Gastrointest Surg 2018;22(2):267–73.

[27] Sharaiha RZ, Kedia P, Kumta N, et al. Initial experience with endoscopic sleeve gastroplasty: technical success and reproducibility in the bariatric population. Endoscopy 2015;47(2):164–6.

[28] Abu Dayyeh BK, Rajan E, Gostout CJ. Endoscopic sleeve gastroplasty: a potential endoscopic alternative to surgical sleeve gastrectomy for treatment of obesity. Gastrointest Endosc 2013;78(3):530–5.

[29] Fayad L, Adam A, Schweitzer M, et al. Endoscopic sleeve gastroplasty versus laparoscopic sleeve gastrectomy: a case-matched study. Gastrointest Endosc 2019;89(4):782–8.

[30] Hill C, El Zein M, Agnihotri A, et al. Endoscopic sleeve gastroplasty: the learning curve. Endosc Int Open 2017;5(9):E900–4.

[31] ASGE/ASMBS Task Force on Endoscopic Bariatric Therapy. A pathway to endoscopic bariatric therapies. Surg Obes Relat Dis 2011;7(6):672–82.

[32] Cotton PB, Eisen GM, Aabakken L, et al. A lexicon for endoscopic adverse events: report of an ASGE workshop. Gastrointest Endosc 2010;71(3):446–54.

[33] English WJ, DeMaria EJ, Brethauer SA, Mattar SG, Rosenthal RJ, Morton JM. American Society for Metabolic and Bariatric Surgery

estimation of metabolic and bariatric procedures performed in the United States in 2016. Surg Obes Relat Dis 2018;14(3):259–63.

[34] Sharaiha RZ, Kedia P, Kumta N, Aronne LJ, Kahaleh M. Endoscopic sleeve plication for revision of sleeve gastrectomy. Gastrointest Endosc 2015;81(4):1004.

[35] O'Brien PE, Hindle A, Brennan L, et al. Long-term outcomes after bariatric surgery: a systematic review and meta-analysis of weight loss at 10 or more years for all bariatric procedures and a single-centre review of 20-year outcomes after adjustable gastric banding. Obes Surg 2019;29(1):3–14.

[36] Althuwaini S, Bamehriz F, Aldohayan A, et al. Prevalence and predictors of gastroesophageal reflux disease after laparoscopic sleeve gastrectomy. Obes Surg 2018;28(4):916–22.

[37] ASGE Bariatric Endoscopy Task Force and ASGE Technology Committee, Abu Dayyeh BK, et al. ASGE Bariatric Endoscopy Task Force systematic review and meta-analysis assessing the ASGE PIVI thresholds for adopting endoscopic bariatric therapies. Gastrointest Endosc 2015;82(3):425–438.e5.

[38] Tate CM, Geliebter A. Intragastric balloon treatment for obesity: review of recent studies. Adv Ther 2017;34(8):1859–75.

[39] Genco A, Lopez-Nava G, Wahlen C, et al. Multi-centre European experience with intragastric balloon in overweight populations: 13 years of experience. Obes Surg 2013;23(4):515–21.

[40] Kotzampassi K, Grosomanidis V, Papakostas P, Penna S, Eleftheriadis E. 500 intragastric balloons: what happens 5 years thereafter? Obes Surg 2012;22(6):896–903.

[41] de Moura DTH, de Moura EGH, Thompson CC. Endoscopic sleeve gastroplasty: from whence we came and where we are going. World J Gastrointest Endosc 2019 May 16;11(5):322–8.

[42] Li P, Ma B, Gong S, Zhang X, Li W. Efficacy and safety of endoscopic sleeve gastroplasty for obesity patients: a meta-analysis. Surg Endosc. Epub 2019 Jun 24.