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Review Article

Sleeve Gastrectomy for Morbid Obesity

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The rising prevalence of morbid obesity and the increased incidence of super-obese patients (BMI >50 kg/m^2) seeking surgical treatments has led to the search for surgical techniques that provide adequate EWL with the least possible morbidity. Sleeve gastrectomy (SG) was initially added as a modification to the biliopancreatic diversion (BPD) and then combined with a duodenal switch (DS) in 1988. It was first performed laparoscopically in 1999 as part of a DS and subsequently done alone as a staged procedure in 2000. With the revelation that patients experienced weight loss after SG, interest in using this procedure as a bridge to more definitive surgical treatment has risen. Benefits of SG include the low rate of complications, the avoidance of foreign material, the maintenance of normal gastro-intestinal continuity, the absence of malabsorption and the ability to convert to multiple other operations. Reduction of the ghrelin-producing stomach mass may account for its superiority to other gastric restrictive procedures. SG should be in the armamentarium of all bariatric surgeons. Nonetheless, long-term studies are necessary to see if it is a durable procedure in the treatment of morbid obesity.

Key words: Gastric, sleeve, Magenstrasse & Mill procedure, gastroplasty, morbid obesity, bariatric surgery

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Introduction

The most commonly performed bariatric procedure in the USA is Roux-en-Y gastric bypass (RYGBP).[1] This is due to its effective long-term weight loss and treatment of co-morbidities, as well as the fact that it is being increasingly performed laparoscopically.[2-4] Initially, the National Institutes of Health supported RYGBP and the vertical banded gastroplasty (VBG) in the treatment of morbid obesity refractory to lifestyle modifications and diets.[5] Laparoscopic adjustable gastric banding (LAGB) was approved in the USA after a lengthy FDA trial. However, there is some concern about its effectiveness due to the lower degree of weight loss compared to RYGBP and VBG and due to the fact that one-third of bands have had to be removed in some studies.[1,6] In 2004, the *Centers for Medicare and Medicaid Services* (CMS) added biliopancreatic diversion (BPD) to the list of recommended bariatric procedures for the surgical management of morbid obesity. This also followed a consensus conference of the American Society for Bariatric Surgery in 2004.[7,8]

Sleeve Gastrectomy (SG) was first described as a modification to the BPD and combined with a duodenal switch (DS) in 1998, and first performed laparoscopically in 1999.[9-11] It consists of a SG as a component of restriction and then duodeno-ileostomy as an intestinal bypass. Benefits of SG in BPD-DS include preservation of the pyloric valve and gastric antrum as compared to distal gastrectomy in standard BPD, resulting in decreased complications

associated with gastrojejunostomy such as marginal ulceration and dumping syndrome.[12] Benefits of DS over BPD include a small duodenal segment that absorbs iron and calcium.

Initial success in bariatric surgery is defined as a >50% loss of excess weight, or 50% EWL.[1,6] Average %EWL is greatest with BPD (range 75-80%), followed by RYGBP (range 60-85%), then VBG (range 50-60%). LAGB has a %EWL in the range of 23-70%.[1,6] Although the initial experience with BPD was associated with higher complications due to a more difficult anatomic dissection, interest in this procedure has grown due to increasing experience with performing BPD-DS laparoscopically, the low rate of complications at large academic centers, and the superior %EWL in the long-term.[13] As experience with BPD-DS grew, surgeons attempted to perform this operation in increasingly obese patients and at times chose to abandon the procedure after only performing the SG.[14]

Patients experience excellent weight loss after SG alone, and multiple recent reports have documented SG as single therapy in the treatment of morbid obesity.[14-23] Nonetheless, the use of SG as a bridge to more definitive surgery is perhaps its most interesting role. In super-obese (BMI >50 kg/m^2) and super-super obese (BMI >60 kg/m^2) patients, the incidence of complications and mortality is increased due to more prevalent co-morbidities and increased difficulty in performing surgery.[24] By using less invasive procedures such as SG as initial management in the super-obese, overall morbidity and mortality may be reduced in this patient population.[24]

The Magenstrasse and Mill Procedure

The concept for sleeve gastrectomy (SG) in the primary treatment of morbid obesity came as a modification of the DS in the USA where patients were treated with the first portion of the DS and only underwent SG. Although similar in technique to the restrictive Magenstrasse and Mill procedure (M&M) developed in the United Kingdom, SG is conceptually different because its efficacy is based on the removal of the grehlin-producing portion of the stomach. First described in 1995 by a group in Leeds, England, the M&M procedure was based on the principal that gastric restriction would lead to weight loss and that these procedures needed to be accomplished by dividing the stomach and not simply stapling it.[25] The Magenstrasse or "street of the stomach" is the name given to the narrow tube of lesser curvature created after division of the proximal greater curvature. Experience from non-divided VBG led surgeons to promote stapled division to avoid gastro-gastric fistulization from the gastric remnant to the restricted portion of the stomach.[25,26] This restricted stomach is created by a similar technique to that used for VBG. In the standard VBG, the EEA is fired from ~6 cm distal to the esophago-gastric junction at about the middle of the lesser curvature.

In the M&M procedure, an EEA stapler is fired along the junction of the antrum and body of the stomach just distal to the *incisura angularis*. After placement of a 32-36 Fr bougie, sequential firings of GIA staplers to the angle of His complete the creation of the Magenstrasse. The remaining antrum is known as the Mill because of the normal grinding that the food bolus undergoes before its expulsion into the duodenum.[25,27] SG is essentially a completion of the Magenstrasse distally, by completely separating the greater curvature of the stomach from the lesser curvature and antrum. However, the M&M procedure by leaving the ghrelin-producing portion of the stomach *in situ*, may lessen the beneficial satiety hormonal effects of the SG. (Figure 1).

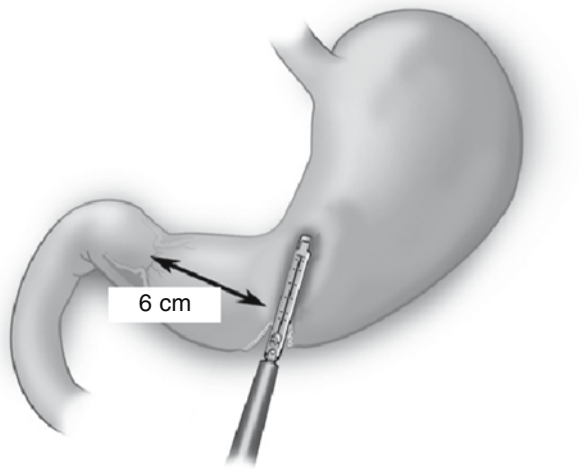

Figure 1. Image of laparoscopic placement of endoscopic stapler, 6 cm proximal to the pyloric valve at approximately the *incisura angularis,* for a laparoscopic sleeve gastrectomy.

Restrictive bands are not placed, because the length of the gastric tube created is believed to provide adequate restriction.[25] Separation of the greater curvature from the rest of the stomach is also advocated, because it is believed that the greater curvature and fundus are particularly elastic and prone to dilation over time.[28] Another benefit of the M&M procedure is the preservation of gastric emptying. Concomitant problems such as diarrhea, dumping and vomiting are also reduced when compared to RYGBP.[29,30] Furthermore, the M&M procedure eliminates the need for a foreign material to create a restrictive band or for placement of a subcutaneous reservoir.[27]

In the largest published series to date analyzing the results of 100 morbidly obese patients who underwent the M&M procedure, mean EWL was 60% after 1 year. Patients were followed for up to 5 years, and no significant weight loss was found after the first postoperative year.[27] In a study of 39 patients and another study of 43 patients 3 years after undergoing the M&M procedure, a decrease in insulin resistance and significantly lower levels of plasma insulin after weight loss were found when compared to control groups.[31,32]

Sleeve Gastrectomy

SG has been gaining popularity because it can be created with relative ease via minimally invasive techniques. Three 10-mm ports are placed: in the supra-umbilical region, between the subxiphoid space and umbilicus, and in the right upper quadrant. Two working 15-mm ports to be used for stapling are placed in the mid-abdomen just medial to the midclavicular lines, and one 5-mm port for retraction is placed in the left upper quadrant (Figure 2). Alternatively, all stapling can be done through one working trocar along the right paramedian line.[33] The assistants stand on either side of the patient and the surgeon stands in-between the legs with the patient in the French position (Figure 3).

SG, as the first operation in a two-stage management of morbid obesity, was first reported in superobese patients who underwent a laparoscopic sleeve gastrectomy followed by a second stage laparoscopic RYGBP.[16] Since that initial study, a total of 15 studies have been published looking at outcomes

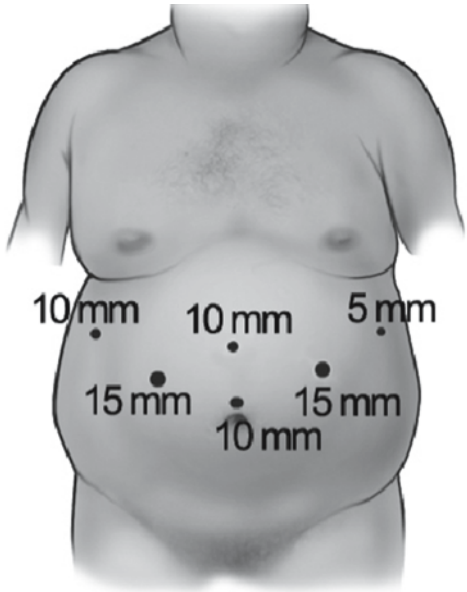

Figure 2. Trocar placement for laparoscopic sleeve gastrectomy.

reported as %EWL after SG with at least 6 months follow-up, of which one is in abstract form.[23] Although % excess BMI loss would be more accurate,[34] most papers did not report this data, and thus %EWL was used. In total, 646 patients were reported with an average BMI of 51 (Table 1).[14,16-24,35-39]

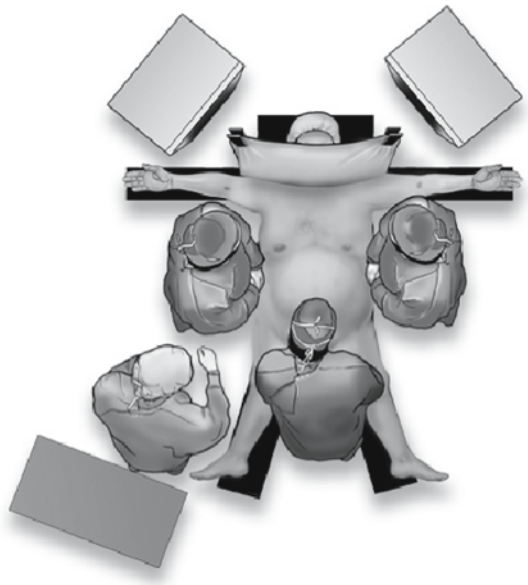

Figure 3. Position of surgeon between the patient's legs in the "French" position, with the camera holder on the patient's right and the other surgical assistant on the patient's left.

The mean EWL is reported as 49% and 56% at 6 and 12 months, respectively. The average follow-up time is 12 months for these studies.

Complications occurred in ~9% of patients and include one intra-operative splenic injury not requiring splenectomy (Table 2).[14,16-24,35-39] Postoperative complications included trocar-site problems such as infection, hernia and hemorrhage. Other postoperative complications include urinary tract infection and atelectasis. There was one documented leak at the transection site with delayed gastric emptying, presenting as gastric dilation and prolonged emesis. There were 4 reported mortalities (<1%): one was due to a traumatic trocar insertion, the second was in the peri-operative period, the third due to primary peritonitis 3 weeks after surgery even though no leak or bowel ischemia was identified at autopsy, and the fourth patient died secondary to a pulmonary embolus 3 months after surgery.[19,20,24,36]

The first reported use of SG as revisional therapy in the treatment of recurrent morbid obesity was in 2003 when Gagner et al[40] reported the treatment of weight regain after laparoscopic BPD-DS with re-operative SG. This patient initially went from a BMI of 64 to 29, but after 17 months was found to be regaining weight. The authors questioned whether she would benefit from further bypass or restriction. An upper GI series found that her gastric pouch had dilated significantly over this period and the decision was made to perform a repeat SG of the dilated stomach. At 10 months after this revision, the patient's BMI was noted to have fallen to 22.[40]

In an effort to avoid gastric dilation in the long-term, surgeons began performing SG with the smallest possible bougies. This was because of the gastric dilation noted after M&M procedures and the reduction of this dilatation after such techniques as micropouch creation for RYGBP.[25,27,28] In our experience, durable weight loss can be observed after SG if a bougie no larger than a 42 Fr is used for primary treatment of morbid obesity. Although not published, we have data that suggest that a 34-Fr bougie may provide superior weight loss without any increased postoperative intolerance. In patients who are candi-

Table 1. Outcome of published series on sleeve gastrectomy

Study	No.	Pre-op BMI	%EWL 6/12 (mos)	Compl (%)	Mort (%)	Weight Regain (%)	Average f/u (mos)	Resolution of co-morbidities
Himpens 2006[35]	40	39	NR/58	5	0	NR	12	NR
Hammoui 2006[36]	118	55	38/49	15	<1	NR	12	NR
Roa 2006[37]	30	41	53/NR	13	0	NR	6	NR
Mognol 2006[38]	10	64	NR/51	0	0	NR	12	NR
Silecchia 2006[39]	41	57	NR	NR	NR	NR	12	60+
Lee 2006[23]	216	49	NR/58†	6	0	4.2§	24	NR
Cottam 2006[24]	126	65	NR/45	14	<1	NR	12	>75
Catheline 2006[17]	4	65	40/NR	25	0	0	6	NR
Langer 2006[18]	23	48.5	46/56	4	0	13	20	NR
Han 2005[19]	60‡	37	71/81	1	1	7	12	HTN (93-100)** DM (100)
Baltasar 2005[20]	31	35-74	56-71	3	3	NR	3-27	HTN (100) DM (100)
Mognol 2005[14]	10	64	NR/51	0	0	NR	12	NR
Langer 2005[21]	10	48	61/NR	NR	NR	NR	6	NR
Milone 2005[22]	20	69	35/NR	5	0	NR	6	NR
Regan 2003[16]	7	63	33*	29	0	NR	11	NR
Total	646							
Mean		51	49/56	9	<1	7	12	60-100

†= %EWL at 24 months was 83, §= weight loss plateau (<4.5 kg lost/6 mos), No. = patients, Compl= complications, Mort= mortality, HTN= hypertension, DM= diabetes mellitus, ‡130 total patients analyzed in calculation of complications, *%EWL at 11 months, + and additional 24% had improvement in co-morbidities, **93% of patients had resolution in HTN and 100% had improvement.

Table 2. Reported complications after sleeve gastrectomy

Reoperations*	29
Leak	6
Prolonged Ventilator Requirements**	5
Strictures	5
Renal Insufficiency	4
Postoperative hemorrhage	2
Atelectasis	2
Pulmonary Embolus†	2
Delayed Gastric Emptying	2
Gastric Dilation	1
Prolonged vomiting	1
Subphrenic abscess	1
Trocar-site infection	1
Urinary Tract Infection	1
Splenic Injury	1
Trocar site hernia	1
Death	4

Complications after 646 Gastric Sleeves for morbid obesity. *indications not reported, ** >24 hour ventilator requirements, †1 resulted in death.[14,16-24]

dates for BPD-DS as a single stage operation, we generally use a 60-Fr bougie because the restriction obtained with a smaller bougie combined with duodeno-ileostomy can be too severe for most patients to tolerate.[10,12,40] Again, new data seem to suggest that smaller bougies may be similarly tolerated in these patients; our analysis is still underway.

Another concern preventing surgeons from embracing SG has been the long staple-line created along the stomach. Concerns regarding staple-line hemorrhage and leak have resulted in attempts to avoid these complications by the use of buttressing material. We initially used non-absorbable material as a buttress along staple-lines in bariatric surgery. However, after one case of bovine pericardium migration in a patients' emesis, this practice was stopped.[42] We subsequently began using an absorbable polymer buttress material along our SG staple-lines and noted decreased instances of staple-line hemorrhage and leak. Use of this material resulted in decreased overall complications and length of stay.[43] Importantly, many groups use a continuous running suture of the staple-lines and note that this adequately controls staple-line hemorrhage and may decrease adhesion formation with a lower overall operative cost.

Because of the rising incidence of super-obese patients, interest in less invasive techniques for the treatment of these patients as a bridge to more definitive surgery has increased. The first study to demonstrate superiority of SG to another weight loss modality was published in 2004. Comparing 20 patients who underwent laparoscopic SG to historical controls of patients treated with an intragastric balloon, superior EWL at 6 months was observed for the SG group.[22] Although the endoscopically-placed intragastric balloon resulted in a %EWL of 24 over this period, SG obtained superior %EWL (33) and was better tolerated.[22]

In another study comparing laparoscopic SG to LAGB, superior EWL was found after 6 months, 61% vs 29%. It was theorized that the resection of the fundus after SG reduced a large area of ghrelin-producing stomach. The authors found decreased levels of ghrelin in the SG patients after 1 and 6 months and no change after LAGB.[21] The removal of large hormonally active areas of the stomach may account for the superior results seen after SG, but studies with longer follow-up are needed.[21]

Recently, Givon-Madhala et al[44] performed 25 consecutive laparoscopic sleeve gastrectomies as sole therapy in patients with average BMI 43 kg/m^2, and reported early percent excess BMI loss of 49 and no complications. Only long-term follow-up studies, however, will ascertain the effectiveness of laparoscopic SG as a sole operation.

Sleeve Gastrectomy in Two-Stage Procedures

To date, there have been only two published reports on patients undergoing staged laparoscopic RYGBP after an initial SG. The first report by Regan and colleagues[16] described 7 patients with an initial average BMI of 63 kg/m^2. They underwent a laparoscopic sleeve gastrectomy as an initial procedure and over an average of 11 months experienced a mean %EWL of 33%. Six of their patients underwent second-stage laparoscopic RYGBP and at very early follow-up had an additional mean %EWL of 40%. There were no mortalities in this series, although 5 minor complications did occur.[16]

Another group described staged laparoscopic

RYGBP but utilized a different initial procedure.[15] These authors note that in the super-obese, exposure of the angle of His is difficult due to the large size of the liver, making sleeve gastrectomy difficult. Therefore, instead of performing an initial restrictive procedure, they performed a modified laparoscopic RYGBP with a low gastrojejunal anastomosis and a larger gastric pouch encompassing the gastric fundus. The low anastomosis obviated the need for exposure of the gastroesophageal junction and the angle of His. They then describe a second-stage procedure to be performed after a 6-12 month period of weight loss where the large gastric fundus portion of the pouch is removed with a "completion" sleeve gastrectomy. This report is only a description of the technique and gives no data on the results of surgery.[15]

The use of second-stage surgery is appealing because it has the potential to reduce morbidity in high-risk super-obese patients. Obviously, this is a new concept that has yet to be proven with prospective study. One key issue to be determined is the timing of second-stage surgery. Some may favor performing a second-stage procedure at a set interval after the initial surgery while the patient is still in a period of rapid weight loss. Others may argue that it is best to wait until weight loss plateaus before performing a second stage, thereby maximizing the effect of the first stage. Another important question that remains unanswered is what operation to perform as a second stage, with RYGBP, DS, and adjustable band all being viable options.

Discussion

As the global population continues to suffer from increasing obesity, surgeons have begun devising safer methods for the management of these patients. By performing less invasive procedures as the initial part of a two-staged surgical regimen, complications and mortality can be kept to a minimum.[15,16] The least invasive procedures for the management of morbid obesity are the ones that result in pure gastric restriction.[21,22] One method for the management of super-obese patients has become the two-stage SG followed by duodenoileostomy in the BPD-DS procedure.[12,21] As experience with this procedure has grown, some surgeons have begun using SG as solitary therapy for the treatment of morbid obesity. This is because of the lack of need for foreign material, excellent patient tolerance by maintenance of gastric emptying, and decreased incidence of nutritional deficiencies.[14,16-22] A very recent study of 23 patients, not included in this analysis, found that after SG, stomach contents actually empty rapidly into the small intestines casting doubt as to whether this procedure is truly restrictive and underscoring the possibility that gut hormonal alterations may play a larger role in satiety and weight loss than currently appreciated.[45]

SG is essentially a modification of the M&M procedure and has gained popularity in the laparoscopic era because of the ease of performing SG via minimally invasive techniques. Although the M&M has adequate weight loss with follow-up of up to 5 years reported in 16 patients, this procedure has not been reported laparoscopically or from outside of one center in Leeds, England.[25,27] Nonetheless, the experience from this procedure has greatly assisted our understanding of the optimal creation of the gastric sleeve. When bougies of 40 Fr have been used in the creation of the M&M, gastric dilatation has been reported. When bougies of 32-36 Fr were utilized, no difference in EWL has been found and no incidence of gastric dilatation has been reported.[27]

In one study, 20 patients who underwent laparoscopic SG over a 48 Fr bougie were followed for an average of 20 months. EWL at 6 and 12 months was 46% and 56%, respectively. All patients were screened for gastric dilatation with an upper GI series. Only 1 patient of 23 (4%) was found to have gastric dilation. SG has been found to have excellent %EWL at 6 and 12 months, but longer-term follow-up is needed to see the effects of gastric dilation over time. An interesting treatment for patients who do suffer from gastric dilatation postoperatively is re-operative SG. This procedure can also be performed laparoscopically and has minimal morbidity.[37,45] As a result, the lack of complete resection of the greater curvature of the stomach may account for the increased rate of gastric dilation seen after M&M procedures when bougies larger than 36 Fr are used. Interestingly, some authors also recommend resecting the antral portion of the greater curvature at the initial surgery to prevent the risk of gastric dilation and the need for re-sleeve gastrectomy in the future.[45]

Conclusion

SG is an excellent procedure for the surgical management of morbid obesity. EWL at 6 and 12 months averages 49% and 56%, respectively.[14,16-24,35-39] Improvement in co-morbidities of obesity, such as hypertension and diabetes mellitus, has been reported to occur in the majority of patients with resolution in 60-100%.[19,20,24,39] When compared to other restrictive procedures,[46] the removal of the greater curvature of the stomach may result in decreased risk of gastric dilation and the removal of ghrelin-producing stomach mass may result in better long-term weight loss. In populations with an increased incidence of gastric cancer, SG is also particularly useful for the reduction in gastric tissue and the maintenance of GI continuity for preservation of a route for endoscopic surveillance. This operation has a low incidence of complications and mortality, and is particularly useful in the super-obese who may benefit from a two-staged procedure.[15,16,24] Although SG may be effective treatment for morbid obesity up to 2 years after surgery, longer term studies (>5 years) are necessary to determine whether SG is a durable procedure in the treatment of morbid obesity.[23]

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