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Review Article

Laparoscopic Vertical Sleeve Gastrectomy for Morbid Obesity. The Future Procedure of Choice?

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Abstract
I report the general experience of performing sleeve gastrectomy defined as "a partial gastrectomy that results in removal of most of the stomach," as a first-stage procedure for morbidly and super-obese people. I also explore its potential as a single procedure evaluating its advantages and disadvantages. This procedure is designed to reduce the size of the stomach and its distention, whereby the patient feels full sooner and their appetite is decreased. Some posit-increased satiety results from the decreased ghrelin, secreted by the fundus, which is resected during this procedure. The advantages of sleeve gastrectomy are as follows: the stomach is reduced without loss of function, pyloric preservation prevents dumping, it requires only 1 day in the hospital, it provides an effective first-stage procedure for super-obese patients, it is useful in patients with disorders such as anemia or Crohn's disease, which preclude intestinal bypass, it can be performed laparoscopically, even in patients who weigh over 500 lbs, no band adjustment is required, it does not result in malabsorption, and it provides a good educational teaching base for doctors lacking experience in the treatment of gastric ulcers. The disadvantages include the risk of stapling complications and its irreversibility.

Key words Sleeve gastrectomy · Partial gastrectomy · Morbid obesity · Restrictive procedure · Gastroplasty · Laparoscopy

Introduction

Sleeve gastrectomy is a term for partial gastrectomy that results in removal of most of the stomach, with the remainder resembling a "banana" or "half moon." The other names for this procedure are "partial gastrectomy," "sleeve gastrectomy," "longitudinal gastrectomy," and "vertical gastrectomy." The mechanism of action of this procedure is that the resulting decrease in the stomach size inhibits distention of the stomach so that it becomes full sooner, thereby increasing the patient's sensation of fullness and decreasing their appetite. Some posit-increased satiety results from the decreased ghrelin, secreted by the fundus, which is resected in sleeve gastrectomy.[1–7]

Initially, partial gastrectomy was devised to resect stomach cancers, but it became part of the bariatric arsenal after it was shown to induce weight loss. Because no one believed the weight loss would be exceptional, sleeve gastrectomy or partial gastrectomy has always been considered as a first-stage procedure, to be followed by either biliopancreatic diversion, which was performed very successfully,[8] or as a first stage before gastric bypass.[9]

With more refined techniques of resecting the stomach, partial gastrectomy has become a bariatric procedure and, in many centers, one of the options offered to patients for weight loss surgery. Unfortunately, despite its initial good results, further studies must be done before we can conclude that it can be done as a single step procedure for morbid obesity.

In this review, I first discuss the Japanese experience of performing partial gastrectomy for cancer, before evaluating its role as a bariatric procedure. I explore the use of sleeve gastrectomy as a first-stage procedure and as a single procedure for morbidly and super-obese patients, noting its advantages and disadvantages.

Cancer and Partial Gastrectomy

Noshiro et al.[10] conducted a retrospective review of the advantages and disadvantages of laparoscopy-assisted

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distal gastrectomy for early gastric cancer. They found that in heavier patients it was difficult to perform a good distal gastrectomy and reconstruction using either Billroth II or Roux-en-Y gastric bypass. In their review of partial gastric resection performed for gastric cancer, they recognized a higher rate of morbidity during and after surgery in obese patients,[11] and noted that it was difficult to perform this surgery in patients with a high body mass index (BMI), who were more likely to suffer serious complications after gastric resection for cancer. Moreover, Roux-en-Y reconstruction was more common in heavier patients.

Shimizu et al.[12] reported partial gastrectomy for the first time at their institution. They found that laparoscopic gastric surgical procedures were safe and feasible for early gastric cancers and submucosal tumors and commented on the associated weight loss, which was initially attributed to the cancer itself, but this is not completely true.

Yasuda et al.[13] reported that laparoscopy-assisted distal gastrectomy is likely to become the treatment of choice for obese patients with early gastric cancer. Their paper is innovative because it is one of the first papers that connects the benefits of distal gastrectomy and laparoscopic treatment with gastric pathology. At the same time, many other investigators were beginning to report the benefits of gastrectomy performed as a bariatric operation. This Japanese group was the first to address the connection between a high BMI and gastrectomy.

Patients with a high risk of gastric cancer, such as those with a close family history, are not suitable candidates for a gastric bypass as the main operation for morbid obesity. Therefore, the sleeve gastrectomy described in this paper may have future merit in Japan and Asia as an operation for morbid obesity, given the high incidence of gastric cancer in this part of the world. With gastric bypass, it is impossible to access the gastric remnant to screen for gastric cancer unless it is done by an open approach or with laparoscopic guidance allowing access to the gastric remnant through the abdomen under general anesthesia. We think that any operation that leaves some of the stomach behind is contraindicated in patients with a high risk of cancer. The options that remain for patients with gastric cancer and morbid obesity are laparoscopic gastric banding or another kind of operation to restrict the stomach. Laparoscopic gastric banding may also be contraindicated in patients at risk of gastric cancer because it would leave adhesions and a foreign body to remove. The main advantage of sleeve gastrectomy is that the first operation has already been performed and part of the stomach is dissected and taken out; therefore, there is less stomach to check or remove for the future of cancer. If gastric cancer does develop, the only operation needed would be completion of gastrectomy since part of the stomach has already been removed.

Safe Weight Loss

Weiner et al.[14] reported that bariatric surgery should be performed on carefully selected patients and in bariatric centers equipped to care for the obese. It is also important to have a multidisciplinary setting that provides lifelong postoperative care. This is true in Europe, Asia, and the United States. Powers et al.[15] showed that weight loss after bariatric surgery varied widely, depending on the length of follow-up and the presurgical characteristics of patients undergoing surgery. Mean weight losses were less than those reported after gastric restriction procedures, but the follow-up was longer and many patients had "super-obesity" before surgery. They discussed the implications of "super-obesity" for weight loss and noticed that weight was regained 2 years after surgery. There was no correlation between the presence or absence of a presurgical psychiatric diagnosis and weight loss at follow-up; nor was there a relationship between the presence of a pre-surgical psychiatric diagnosis and various mental health parameters. This was associated with gastric restriction or gastroplasty only.

Parikh et al.[16] reported that laparoscopic bariatric procedures are generally safe for super-obese patients. Laparoscopic adjustable gastric banding, the least invasive procedure, resulted in the shortest operative times, the lowest conversion rate, the shortest hospital stay, and the lowest morbidity in this high-risk cohort of the super-obese patients; however, the difference in percentage of excess weight loss after the Roux-en-Y gastric bypass and the laparoscopic adjustable gastric banding at 2 and 3 years was not significant. After 1, 2, and 3 years, respectively, the mean percentages of excess weight loss achieved by laparoscopic adjustable gastric banding were 35%, 46%, and 49%; those achieved by Roux-en-Y gastric bypass were 58%, 56%, and 57%; and those achieved by biliopancreatic diversion were 61%, 69%, and 77%, respectively.

Sleeve Gastrectomy After Other Operations

Gagner and Rogula[8] performed repeat laparoscopic gastric sleeve resection for inadequate weight loss after biliopancreatic diversion or duodenal switch, which resulted in further weight reduction. This was done using a greater curvature dissection with bovine pericardium for reinforcement, achieving good results with lower morbidity and mortality rates than redo anastomosis.

In duodenal switch or biliopancreatic diversion, the gastrointestinal tract is dissected below the pylorus in

the first portion of the duodenum. The anastomosis with the ileus is done at the duodenum below the pylorus to allow for a long bypass with a more malabsorptive procedure. This technique is done either by itself or with the addition of a sleeve gastrectomy; in this case to add a restriction of the stomach to the malabsorption of the biliopancreatic diversion.

Sleeve Gastrectomy as a First-Stage Procedure

Cottam et al.[17] performed laparoscopic sleeve gastrectomy as the first stage for achieving weight loss and reducing comorbidities in patients who were super-obese, before performing laparoscopic Roux-en-Y gastric bypass. They reported that the staging concept of laparoscopic sleeve gastrectomy followed by laparoscopic Roux-en-Y gastric bypass is a safe and effective surgical approach for high-risk patients seeking bariatric surgery. The question remains as to whether a large enough laparoscopic sleeve gastrectomy can preclude the need for a second procedure.

Mognol et al.[18] reported that laparoscopic sleeve gastrectomy is safe and can be integrated into a bariatric surgical program with good results in terms of weight loss and quality of life. Laparoscopic sleeve gastrectomy can be a first-stage procedure before gastric bypass or duodenal switch or a one-stage restrictive long-term procedure. Their results show an average excess weight loss with a BMI at 1 year of 51% and 23 kg/m^2, respectively.

Regan et al.[9] reported their experience of performing two-stage laparoscopic Roux-en-Y gastric bypass in super-obese patients. They performed laparoscopic sleeve gastrectomy with second-stage Roux-en-Y gastric bypass and concluded that this approach was a feasible and reasonable alternative for the high-risk super-obese patient with a BMI greater than 55. The mean weight and BMI of patients undergoing sleeve gastrectomy were 181 kg and 63, respectively. Prior to the second-stage procedure, the mean weight was 145 kg and the BMI was 50, which accounted for a 37 kg weight loss equivalent to a 33% excess weight loss.

The use of modified sleeve gastrectomy or partial gastrectomy associated with gastric banding is shown in Fig. 1. During this procedure, we used the fundus to create the pouch for gastric banding. After the gastric band is placed around the stomach and sutured in place, partial gastrectomy is achieved, creating a smaller stomach below the band. This provides several advantages. One advantage is that the patient requires less adjustment of the band; another is that the patient does not need to come to the clinic for 4–6 months after the procedure. However, the most important advantage of combining banding and sleeve gastrectomy is the faster weight loss in the first few months than achieved by gastric banding alone. We have performed partial gastrectomy after gastric banding with great success and weight loss exceeding 30% at 6 months[19] (Table 1).

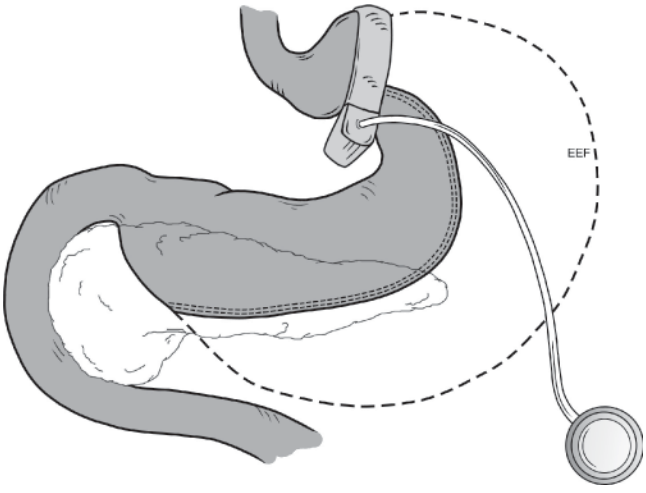

Fig. 1. Combined banding and sleeve gastrectomy

Table 1. Characteristics and changes in body mass index of ten patients who underwent laparoscopic gastric band/sleeve (restriction) gastrectomy

	Patient no.									
	1	2	3	4	5	6	7	8	9	10
Age (years)	37	45	36	46	55	57	23	47	34	51
Sex	F	F	F	F	F	F	F	M	F	F
Race/Ethnicity	H	C	H	C	C	H	C	C	H	C
Number of co-morbidities	5	7	5	7	5	8	6	9	5	7
Operative time (min)	69	71	69	71	80	85	65	74	82	92
Blood loss (cc)	30	20	30	20	25	30	30	20	40	30
BMI, preoperative (kg/m^2)	65	64	57	52	61	42	46	53	59	50
BMI, 180 days postoperative (kg/mg^2)	45	43	41	41	40	34	35	40	39	36
Percent decrease in BMI	31%	33%	28%	21%	34%	19%	24%	25%	34%	28%

H, Hispanic; C, Caucasian; BMI, body mass index

Milone et al.[20] reported the superiority of laparoscopic sleeve gastrectomy over endoscopic intragastric balloon as a first-stage procedure in 20 super-obese patients. These 20 patients who underwent laparoscopic sleeve gastrectomy achieved faster and greater weight loss than those treated with the BioEnterics intragastric balloon (BIB). This data were collected after 6 months and suggest that laparoscopic sleeve gastrectomy is a good first-stage procedure before any other procedure for bariatric surgery.

Sleeve Gastrectomy as a Single Operation

Baltasar et al.[21] reported that laparoscopic sleeve gastrectomy could be used in a different setting. They assessed patients with a very high BMI at the first stage of the duodenal switch, even before gastric banding, and concluded that laparoscopic sleeve gastrectomy may become the ideal operation for staging in patients with a BMI greater than 55, for treating morbidly obese patients with severe medical conditions, and for patients with a lower BMI, as an excellent alternative to adjustable bands and for conversion of gastric banding. We believe the more restrictive sleeve gastrectomy could become a first-stage and, at times, a single-stage operation for most patients, as reported recently by Lee et al. at SAGES.[22]

Moon Han et al.[23] reported their findings on laparoscopic sleeve gastrectomy in a review of 130 Korean patients. They concluded that laparoscopic sleeve gastrectomy without the second-stage duodenal switch operation had been an effective weight loss operation thus far. They reported resolution of dyslipidemia in 75%, diabetes in 100%, hypertension in 93%, and joint pain in 100% of their patients within the first year. In 60 patients, excess weight loss was 71% at 6 months, and 83% at 12 months. Moreover, 12 months after laparoscopic sleeve gastrectomy, the average patient BMI was 9.2 and the median weight loss was 24.6 kg. This technique involved placing a gastric tube over a 48-F bougie.

Langer et al.[24] also found that laparoscopic sleeve gastrectomy was highly effective for weight reduction in morbidly obese patients, even as the sole bariatric operation. Gastric dilatation was found in only one patient during short-term follow-up. Weight regained following laparoscopic sleeve gastrectomy may require conversion to Roux-en-Y gastric bypass or duodenal switch. Obviously, follow-up is necessary to evaluate the long-term results. Patients who underwent laparoscopic sleeve gastrectomy achieved a mean excess weight loss at 6 and 12 months postoperatively, of 46% and 56% respectively. This shows that sleeve gastrectomy is effective as a single procedure. This study included both super-obese and morbidly obese patients and one of its other conclusions was that sleeve gastrectomy works for both types of obesity.

Almogy et al.[25] compared morbidly obese patients who underwent either the duodenal switch procedure or longitudinal gastrectomy, which is comparable to the sleeve gastrectomy. The median weight loss and median percentage of excess weight loss at 12 months were 44.5 kg and 45.1%, respectively. They concluded that longitudinal gastrectomy is a safe and effective option for high-risk morbidly obese patients. Weight reduction is accomplished by limitation of the caloric intake and longitudinal gastrectomy can be offered to high-risk morbidly obese patients as an interim procedure to help decrease the perioperative risks before the duodenal switch.

The problem we must address is what will happen to the stomach in 2–5 years? To prevent regrowth, should we consider adding some type of banding or restriction to the sleeve gastrectomy procedure?

Ghrelin and Sleeve Gastrectomy

Lin et al.[1] reported that compared with morbidly obese patients, lean controls had significantly lower baseline levels of ghrelin. A divided gastroplasty creating a small proximal gastric pouch resulted in significantly early declines in circulating ghrelin levels, which were not observed after gastric procedures. This may help explain the loss of hunger and rapid weight loss observed after bypass surgery.

According to Lin et al.,[1] Roux-en-Y gastric bypass surgery results in a remarkable change between pre- and postoperative ghrelin levels, not observed after vertical banded gastroplasty. They suggested that the complete division of the stomach, with the formation of a small vertical pouch, contributed to the decline in circulating ghrelin levels, and that the decline in ghrelin levels following Roux-en-Y gastric bypass is not a gradual process, but occurs early after the procedure.

Christou et al.[26] reported that the failure to lose weight after Roux-en-Y gastric bypass did not correlate with the preprandial ghrelin levels. The ghrelin levels were inversely proportional to the BMI and did not correlate with satiety. These data support the belief that increased plasma ghrelin levels do not contribute to inadequate weight loss after Roux-en-Y gastric bypass, and this answers the question about the role of ghrelin in gastric bypass blood levels. Similar results were reported by Langer et al.[7] who found that resection of the gastric fundus, the predominant area of human ghrelin production, reduces ghrelin secretion after laparoscopic sleeve gastrectomy, resulting in lower ghrelin levels than after gastric bypass.

Human obesity is associated with insulin resistance and low ghrelin levels.[4–6] Therefore, a lower ghrelin level alone as a result of surgery cannot account for the normalization of glucose metabolism in these patients. The mechanism of the decline in ghrelin levels is not clear. One of the effects may be secondary to the paracrine effect exerted by endogenous gastrointestinal hormones such as GLP-1, GLP, ghrelin, and others.[2,3,27–29] In our earlier paper, we pointed out that not only is production decreased after sleeve gastrectomy, but ghrelin and GLP-1 are produced locally and therefore, they are biologically activated locally. Thus, it could be an "on–off" mechanism or an increase or decrease in the secretion of these hormones[27] (Fig. 2).

Langer et al.[7] reviewed studies on the effects of sleeve gastrectomy on ghrelin levels and found that different changes in plasma ghrelin levels were reported after gastric banding, Roux-en-Y gastric bypass, and biliopancreatic diversion. They performed a prospective study comparing plasma ghrelin levels and weight loss after laparoscopic sleeve gastrectomy and laparoscopic adjustable gastric banding in 20 patients. Their conclusion was that as a consequence of resection of the gastric fundus, the predominant area of human ghrelin production, ghrelin is significantly reduced after laparoscopic sleeve gastrectomy, but not after laparoscopic adjustable gastric banding. This reduction remains stable 6 months postoperatively, which may contribute to the superior weight loss achieved by sleeve gastrectomy over laparoscopic adjustable gastric banding.[7] This is an exceptional paper[7] which reveals the difference between adjustable gastric banding and sleeve gastrectomy. Another study also showed that sleeve gastrectomy achieved good weight loss in the long term, almost comparable with that achieved by gastric bypass.[22]

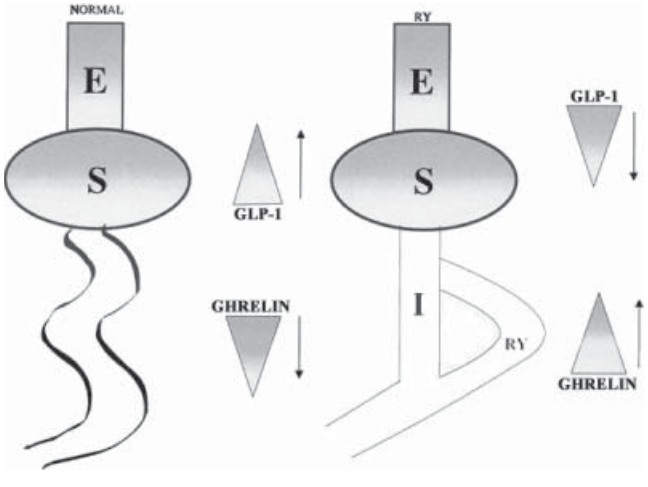

Fig. 2. Reversal secretion hypothesis after gastric bypass. *E*, esophagus; *S*, stomach; *I*, intestine; *RY*, RY gastric bypass; *Normal*, normal anatomy

Surgical Procedure

Good visualization of the pylorus and incisura angularis is important during sleeve gastrectomy. Dissection starts 7–10 cm from the pylorus on the greater curvature. Dissection of the greater omentum is done using a harmonic scalpel (Ethicon, Johnson & Johnson, Cincinnati, OH, USA) followed by total dissection of the area around the left crura to avoid splenic injury. We used green staples (US Surgical, Norfolk, CT, USA) and SeamGuard (Goretex, Tempe, AZ, USA) or the new, thinner peri-strips (Synovis, St. Paul, MN, USA). Initially, we used blue staples but because the stomach was so thick in some patients, restapling became necessary. Therefore, we started using green staples, the disadvantage of which is that they require a 15-mm port. This is a small price to pay for the safety of the patient. We think that the use of peri-strips or SeamGuard[30] has decreased the risk of leaks and bleeding. We initially used a 48-F bougie but now use either a 29-F scope or a 32-F bougie. The latter is in accordance with the findings of a group in San Francisco.[22]

Figure 3 shows the positions of the trocars and Fig. 4 shows a vertical sleeve gastrectomy and the anatomical positions of the other organs. The stomach is placed in a bag to prevent wound infection at the level of the port, and pulled through a 15-mm port. The stomach is

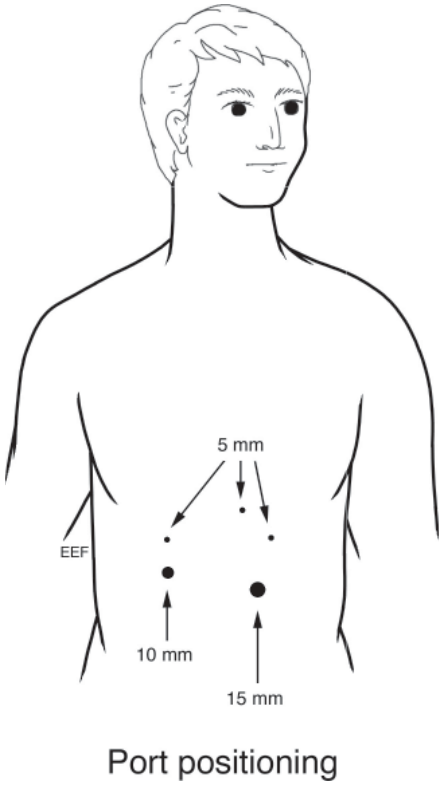

Fig. 3. Trocar positions for laparoscopic sleeve gastrectomy

Table 2. Advantages and disadvantages of sleeve gastrectomy

Advantages	Disadvantages
The stomach size is reduced without loss of function	Stapling complications
Pyloric preservation prevents dumping	Irreversibility
It requires only 1 day in hospital	
It is an effective first-stage procedure for super-obese patients	
It is useful for patients with conditions such as anemia or Crohn's disease, which preclude intestinal bypass	
It can be performed laparoscopically, even in patients who weigh over 500 lbs	
No band adjustment is required	
There are no problems with malabsorption	
It provides a good educational teaching base for resident doctors lacking experience with gastric ulcer surgery	

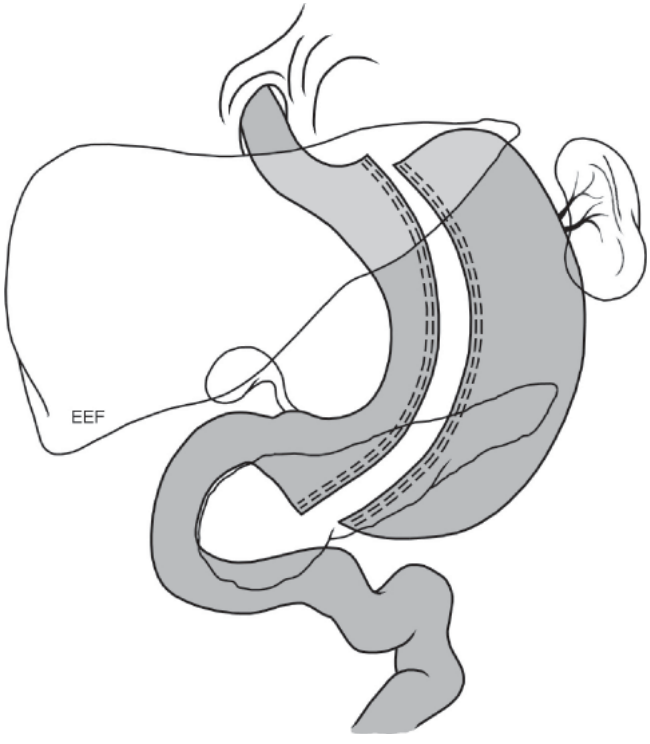

Fig. 4. Vertical sleeve gastrectomy

always retrieved and sent for gross pathology only. The most common complaint by the patient after surgery was nausea, but no vomiting was reported.

The advantages and disadvantages of sleeve gastrectomy are summarized in Table 2. In brief, the advantages are as follows:

1. The stomach is reduced without loss of function
2. The pyloric preservation prevents dumping
3. The patient can be discharged from hospital within 1 day
4. It provides an effective first-stage procedure for super-obese patients
5. It is useful for patient with conditions such as Crohn's disease, which preclude intestinal bypass
6. It can be performed laparoscopically, even in patients who weigh over 500 lbs
7. No band adjustment is required
8. There are no problems with malabsorption
9. It provides a good educational base for resident doctors lacking experience in the surgical treatment of gastric ulcers

The disadvantages include the following:

1. The risk of stapling complications
2. The irreversibility of the procedure

Conclusion

In consideration of everything that has been said about the sleeve, partial or vertical gastrectomy, I believe that it is indicated in two main areas: as a first-stage procedure for super obesity before gastric bypass or biliopancreatic diversion; and as a possible single procedure for super-obese and morbidly obese patients since the weight loss it achieves is close to that of other restrictive procedures, but only in certain centers and with close follow-up and the option to perform a second procedure in the future. These conclusions are important because sleeve gastrectomy is a safer operation than gastric bypass or biliopancreatic diversion, with lower morbidity and mortality. It can also be performed easily in super-obese patients. I believe that with advanced technology and good stapling techniques, sleeve gastrectomy could become the procedure of choice, with mortality and morbidity close to zero, for morbidly obese patients who want to achieve at least 50% excess weight loss within 18 months. Myself and colleagues are continuously developing this technique, as are many other surgeons around the world, and we are confident that the sleeve gastrectomy will enter into the main group of procedures offered to bariatric patients as a

single and sole procedure. However, more data must be collected and a 5-year follow-up study needs to be published.

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