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Sleeve Gastrectomy – A Restrictive Procedure?

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Background: Diet and surgically-induced weight loss have been shown to lead to alterations in motor and sensory function of the stomach. We investigated the clinical outcome and gastric emptying of solid foods in morbidly obese (MO) patients following sleeve gastrectomy (SG).

Methods: We studied 23 MO patients [(7 males, 16 females), mean age 38.9 ± 11.0 years (range 20-64 years), mean weight 135.1 ± 19.0 kg (range 97-167 kg), mean BMI 47.2 ± 4.8 kg/m^2 (range 39.6-56.0 kg/m^2)] who each underwent a sleeve gastrectomy (SG) for weight reduction. At the monthly follow-up visits, variations in weight and BMI changes, postoperative meal size and frequency, and presence of gastrointestinal symptoms were recorded. 11 patients underwent scintigraphic measurement of the gastric emptying of a solid meal pre- and 6 months postoperatively.

Results: A significant reduction in patients' weight was evidenced at 6 and 12 months postoperatively [98.6 ± 11.8 kg and 87.0 ± 10.7 kg respectively (*P*=0.001)]. BMI decreased to 35.2 ± 4.3 kg/m^2 at 6 months and to 31.1 ± 4.5 kg/m^2 at 12 months, respectively (*P*=0.001). Although meal size was drastically reduced, meal frequency increased postoperatively in 12 patients (52.2%). Only 5 patients (21.8 %) reported occasional vomiting after meals following SG. The gastric emptying half-time (T1/2) accelerated (47.6 ± 23.2 vs 94.3 ± 15.4, *P*<0.01) and the T-lag phase duration decreased (9.5 ± 2 min vs 19.2 ± 2 min, *P*<0.05) postoperatively. The percentage of the meal emptied from the stomach 90 min after consumption increased significantly after SG (75.4 ± 14.9% vs 49.2 ± 8.7%, *P*<0.01).

Conclusions: This study indicates that following SG, the stomach empties its contents rapidly into the small intestine and symptoms of vomiting after eating (characteristic of restrictive procedures) are either absent or very mild. Therefore, the term 'restrictive' is possibly ill-advised for this new bariatric operation. It remains for other mechanisms of energy intake reduction, such as intestinal distension and satiety signals through gut hormones to be investigated, to comprehensively explain precisely how this 'food limiting' procedure results in weight loss.

Key words: Morbid obesity, sleeve gastrectomy, bariatric surgery, scintigraphy, gastric emptying

Introduction

As the epidemic of obesity continues,[1] the number of elderly[2] and extremely obese patients with a high incidence of co-existing medical problems (diabetes, hypertension, sleep apnea, etc.) is also on the rise.[3,4] When surgery for weight reduction is considered in the sub-group of super- and super-super-obese, patients run a high operative risk.[2,5]

In an effort to minimize surgical risks in these patients, the sleeve gastrectomy (SG) was introduced into the anti-obesity armamentarium, initially as a first-step procedure followed by either biliopancreatic diversion with duodenal switch (DS)[2] or Roux-en-Y gastric bypass (RYGBP).[5]

The positive results coupled with significant reduction in morbidity and no mortality reported in high-risk patients undergoing a SG, compared to the same parameters after the one-step procedures, has encouraged others not only to utilize this procedure as the first part of more complicated bariatric operations but also as a definitive operation for permanent weight loss in morbidly obese patients.[6]

This operation is considered as purely restrictive, as are the vertically banded gastroplasty (VBG), the

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silastic ring vertical gastroplasty (SRVG) and the laparoscopic adjustable gastric banding (LAGB).[6] Thus, the reduction in the energy intake and the weight loss associated with SG are presumably induced by the same mechanism(s) as in the other restrictive procedures. It is generally believed that after restrictive-type surgery, small amount of foods can be consumed and accommodated in the tiny gastric pouch that is constructed in continuation with the esophagus.[7] The passage of the food through the pouch outlet into the distal stomach and the rest of the gut is mechanically delayed (gastric outlet reinforcement in VBG and SRGB or the band itself), resulting in energy intake reduction and finally in weight loss.[3,4] Because there is strong evidence that slow gastric emptying following diet[8] or surgically-induced weight loss,[9] could be a dominating mechanism responsible for less food ingestion and thus reduced energy absorption in obese patients,[10] it is speculated that delayed gastric emptying due to mechanical restriction to food plays a significant role in weight reduction after restrictive-type bariatric surgery.

This prospective study was undertaken in an attempt to investigate the clinical outcome and the gastric emptying of solid foods following SG, while comparing these findings with the previously published emptying patterns of the current purely gastric restrictive operations.

Patients and Methods

Twenty-three morbidly obese patients (7 male, 16 female) who had undergone laparoscopic (19 patients) or open approach (4 patients) SG for weight loss, were studied. The patients' demographic characteristics are shown in Table 1. Selection criteria for SG in this study were: 1) BMI >55 (1 patient); 2) BMI >50 with severe co-morbidities such as sleep apnea, diabetes, hypertension, previous cardiac infarction, etc. (6 patients); and 3) BMI 35-49.9 and patient's preference (16 patients). Weight, BMI, meal size and frequency using a quantitative food-frequency questionnaire,[11] postprandial feeling of fullness and satiety, the presence of dumping syndrome and GI symptoms such as nausea, vomiting, heartburn, dysphagia and indigestion were all recorded pre- and postoperatively during monthly follow-up visits. The percentage of excess BMI loss (%EBMIL) was calculated using the formula %EBMIL = 100 – [(Follow-up BMI – 25/ Beginning BMI – 25) x 100].[12] Gastric emptying studies for solids were performed pre- and 6 months postoperatively in 11 patients from this group that participated in the study. The demographic characteristics of this group are shown in Table 2. Written consent was obtained from each patients. For this part of the study, permission was given by the local ethics committee.

Table 1. Patients' demographic characteristics, postoperative weight and BMI alterations (values expressed as mean ± SD)

	Patients (n=23)	6th month	12th month
Age (years)	38.9 ± 11.9		
Male/Female	7/16		
Weight (kg)	135.1 ± 19.0	98.6 ± 11.8*	87.0 ± 10.7*
BMI (kg/m^2)	47.2 ± 4.8	35.2 ± 4.3*	31.1 ± 4.5*
%EBMIL		54.1%	72.5%

BMI = body mass index, % EBMIL = % excess body mass index loss. *P=0.001.

Operative Procedure

Under general anaesthesia, the patient was placed in the lithotomy position with the surgeon positioned between the legs. A pneumoperitoneum was induced with CO_2 with a Veres needle and maintained at a pressure of 16 mmHg. Five trocars were inserted into the peritoneal cavity. The gastrocolic ligament was opened adjacent to the stomach start-

Table 2. Demographic characteristics, postoperative weight and BMI alterations in solid emptying study participants (values expressed as mean ± SD)

	Patients (n=11)	6th month post-op
Age (years)	41.5 ± 10.7	
Male/Female	3/8	
Weight (kg)	135.9 ± 19.7	99.4 ± 13.7*
BMI (kg/m^2)	48.0 ± 5.9	35.3 ± 4.2*
%EBMIL		55.2%

BMI = body mass index, % EBMIL = % excess body mass index loss. *P=0.003.

ing 7 cm from the pylorus, using the impedance coagulator (Ligasure®, Tyco, Mansfield, MA, USA). The greater curvature of the stomach was freed up to the cardioesophageal junction. A 34-Fr orogastric tube was then inserted by the anesthesiologist into the stomach, and was directed towards the pylorus. Using laparoscopic linear staplers (EndoGIA®, Tyco) with green cartilages, the stomach was divided parallel to the orogastric tube along the lesser curvature. The excision line was then reinforced with a running 2-0 polypropylene suture. By inserting a nasogastric tube filled with water, the volume of the remaining stomach was measured and determined to be between 80 and 143 ml, with a mean of 125 ml. A methylene blue test was then carried out, and a drain was placed at the left subdiaphragmatic space. The resected stomach was then removed from the peritoneal cavity and the wounds closed. This approach was utilized in 19 patients. In addition four patients with simultaneous umbilical or incisional hernia repair were subjected to sleeve gastrectomy using a mid-line laparotomy with the same operative steps and instruments.

Postoperative Follow-up

A barium swallow was performed on the 2nd postoperative day and oral fluids were started if leak or mechanical obstruction were absent. Patients were discharged on the 3rd or 4th postoperative day, unless complications occurred resulting in prolongation of the hospital stay. Patients were followed-up at monthly visits and were asked to complete the aforementioned relevant questionnaire.

Gastric Emptying Study

Eleven patients underwent gastric emptying studies using radioisotopic technique before and 6 months after the operation. After an overnight fast, each patient ingested a standard solid food meal consisting of a hamburger labeled with 74 MBq 99mTc-sulfur colloid and 140 g of fresh tomato. The hamburger contained 100 g of minced beef meat, 20 g of toasted bread, 10 ml of olive oil and half an egg. The total calorie content of the meal was 390 Kcal (52% fat derived, 32% protein derived, 16% carbohydrate derived) and was consumed within 10 min.

Data acquisition: Scintigraphic imaging was performed with a γ-camera (Millenium, GE Medical Systems, Milwaukee, WI) equipped with a LEGP collimator. The passage of the meal was evaluated by a digital computer. Immediately after completion of the meal, the subjects were positioned sitting in front of the γ-camera. Anterior static images of the abdominal field were acquired (60 sec for each frame) at regular time intervals every 10 min for a total of 90 min. The camera captured frames and transmitted them to a computer for analysis and storage.

Qualitative and quantitative analysis was performed on every image by drawing regions of interest enclosing the stomach. Time 0 was considered the time of meal completion. The retention of the meal in the stomach at time 0 was defined as 100%. Time-activity curves were generated using a gastric region of interest for each of the views. Quantitative parameters were determined as percentage gastric emptying (% GE) at 90 min, half-time (min) based on an exponential fit. The counted radioactivity over the gastric area was corrected for isotope physical decay. T-lag is the period of time in which gastric emptying is <10% of the initial count, and the T1/2 is the time interval between the completion of the meal and the point at which half of the meal has left the stomach.[13]

Statistical Analysis

Statistical analysis of data was performed using the SyStat v 10.0 program (SPSS Inc, Chicago, IL). Continuous variables were expressed as mean ± standard deviation. Differences in clinical and laboratory parameters before and after surgical treatment were examined using paired Wilcoxon signed rank test. Level of significance was set at $P<0.05$.

Results

All patients tolerated the operation well and recovered within a short time period. No conversions to laparotomy were necessary. Three patients (15.8%) from the laparoscopic group who had postoperative hemorrhaging were managed conservatively with blood transfusions. One patient (5.3%) from the same group developed a leak at the upper part of the excision-line, which was treated with the insertion of a nasoduodenal tube and tube feeding for 2 weeks. One

patient (5.6%) who had also undergone a laparoscopic SG developed a delay in the postoperative emptying of the proximal gastric pouch due to edema of the excision-line and was treated with I.V. hyperalimentation for 2 weeks. A new upper GI study then revealed normal passage of barium in the distal stomach, and the patient was discharged on oral fluids for 1 more week and a "soft diet" thereafter. No deaths or long-term complications occurred in this series.

Postoperative weight and BMI changes are also shown in Table 1. All patients were consuming significantly smaller sized meals postoperatively and their appetite was significantly reduced compared to preoperative status. Daily meal frequency increased postoperatively from 2-3 (range 1-5) before sleeve gastrectomy, to 5-6 (range 3-9) much smaller meals postoperatively in 12 patients (52.2%). The remaining 11 patients (47.8%) were constantly snacking preoperatively (8-12 daily meals). In all patients the frequency of meals was reduced postoperatively to 2-3 (range 2-6) small regular meals daily. After the SG procedure, all patients noted a feeling of fullness with very little food (e.g. 100 ml of yoghurt), while postprandial satiety was provoked with significantly less food than preoperatively.

Five patients (21.8%) reported occasional vomiting after a larger than usual meal consumption postoperatively. However, the remaining 18 patients (78.2%) did not experience vomiting postoperatively and reported that they had quickly become accustomed to the appropriate meal size in order to avoid nausea or vomiting.

Gastroesophageal reflux (GER) was evident in 8 patients preoperatively. In 3 patients, these symptoms disappeared completely and in one patient they improved significantly postoperatively. In 3 patients, the GER symptoms remained unchanged and were aggravated in only one patient postoperatively. Two more patients who were GER symptom-free preoperatively reported evidence of reflux disease following the operation. Two patients had unchanged heartburn pre- and postoperatively and one had aggravated pre-existing heartburn symptoms. Two more patients had complete remission or vast improvement of their existing preoperative symptoms.

No patient developed dumping syndrome, diarrhea or a peptic ulcer postoperatively. One patient complained of intermittent dysphagia which gradually improved, for solid foods for the first 3 months after the procedure. Three patients developed constipation, 9 experienced temporary hair loss and one patient developed gallbladder stones and subsequently underwent a laparoscopic cholecystectomy 1 year after the sleeve gastrectomy.

Quality of life was excellent in all patients, and there were no major complaints. All patients in this series were absolutely positive that they would again undergo the same bariatric procedure. Finally, one patient was subjected to a duodenal switch procedure 12 months following SG; her weight loss was 21 kg and her BMI was 48.6 kg/m^2 pre- and 40.3 kg/m^2 postoperatively just before the second procedure.

Solid Gastric Emptying

In each patient, solid emptying was characterized by a lag phase followed by a linear emptying. The lag phase (which represents the time from the end of the meal to the beginning of the emptying into the duodenum and small intestine) was significantly decreased following the SG from 19.2 min preoperatively to 9.5 min postoperatively (19.2 ± 4.3 min vs 9.5 ± 5.5 min, $P<0.05$). The T1/2 (the time elapsed from completion of the meal to the point at which half of the meal had left the stomach) accelerated significantly postoperatively – from 94.3 min before to 47.6 min after SG (94.3 ± 15.4 min vs 47.6 ± 23.2 min, $P<0.01$). The percentage of gastric emptying (% GE) which indicates the portion of the meal that left the stomach at the end of the observation period of 90 min, also increased significantly postoperatively – from 49.2% preoperatively to 75.4% after sleeve gastrectomy (49.2 ± 8.7% vs 75.4 ± 14.9%, $P<0.01$).

Discussion

Laparoscopic sleeve gastrectomy has recently been introduced as a first-step bariatric procedure in an effort to minimize surgical risk for patients with BMI>55 kg/m^2, followed by either laparoscopic duodenal switch[14] or Roux-en-Y gastric bypass.[5] Initial results are very promising, and the use of this simple procedure is gaining popularity among laparoscopic bariatric surgeons. Patient selection criteria for SG are now becoming wider and even include morbidly obese patients with lower BMI.[6]

Although the follow-up period in the existing series is still relatively short, early weight loss results are encouraging the performance of SG as a single-stage procedure for patients with BMI 35-50.[6] This operation may well become the gold standard for such patients, providing the current positive results are maintained over the long term. This procedure is associated with lower mortality than the gastric bypass, and if weight loss proves inadequate, the patient has the further option of a second procedure for conversion to either bypass or duodenal switch.[2,5,6,14] In this event, the risk of mortality and morbidity is markedly lower because the patient is fitter with improved co-morbidities, having already lost weight and the conversion itself is less invasive and time-consuming.[14] It could also replace gastric banding, because neither foreign body is used, nor adjustment needed and the orexigenic ghrelin producing gastric fundus is removed.[6]

This novel procedure is so far considered restrictive. It is generally believed that SG achieves weight loss by restricting the amount of food that can be consumed, with no malabsorption.[6] However, there are differences between SG and the traditional representatives of the restrictive procedures (VBG and adjustable gastric banding). The latter result in weight loss because of the creation of a small gastric pouch in continuation of the esophagus that can only accommodate small volumes of food and by delaying the passage of the food into the distal stomach by mechanical means (e.g. the outlet reinforcement in VBG and the band itself). In order to achieve energy intake reduction and result in acceptable weight loss, the pouch volume for both restrictive procedures has to be tiny and not exceed 15 cc.[3,4] In SG, food intake is not restricted by the introduction of foreign material, the volume of the remaining stomach is larger by far (up to 150-200 cc).[6,15] while the gastric fundus, the major food storage compartment and upper part of the body of the stomach, including the gastric pacemaker, are removed.

Another operation that is considered restrictive is the Magenstrasse and Mill (M&M) gastroplasty, where a lesser curvature tube is created and conveys food from the esophagus to the antral Mill. Normal antral grinding of solid foods and antro-pyloro-duodenal regulation of gastric emptying and secretion are preserved.[16] However, the M&M differs from the SG in that the gastric fundus is not resected and therefore the food storage ability and ghrelin production are not reduced.

As far as gastric emptying is concerned, our results indicate that gastric emptying for solids occurs faster after SG. The time from the termination of a meal to the beginning of emptying into the duodenum was significantly shorter following resection of part of the stomach, indicating an alteration in gastroduodenal coordination. Excision of the fundus and absence of receptive relaxation, as well as alterations in the contractile activity in the proximal stomach are possible explanations for the decreased T-lag phase found in this study. The time required for half of the solid meal to leave the stomach (T1/2) and the percentage of the meal emptied into the small intestine at the end of the 90-min observation period (%GE) were also significantly altered following SG, indicating that the stomach empties solid foods rapidly and possibly incompletely processed into the duodenum.

This study does not support the findings of a previous investigation on gastric emptying conducted in patients 3 years after the M&M procedure.[17] In that study, no statistically significant difference was found in the gastric emptying of solid foods in the 13 patients subjected to the M&M operation, compared to 10 morbidly obese volunteers and 7 normal weight controls. Although gastric emptying half-times (T1/2) for solids was 140 min (86-220) in the MO group and faster by 79 min (46-150) in the M&M group, the difference did not reach statistically significant levels. Since preoperative emptying data of those patients subjected to the M&M operation was absent in this study, we believe that the variations in the emptying patterns after the M&M and SG procedure respectively can be attributed to the presence of the gastric fundus in connection with the antrum that can accommodate foods.

Previous studies of gastric emptying after restrictive procedures (gastroplasty) have shown conflicting results. Some conclude that gastric emptying of solids is slower after gastroplasty,[18-20] but others have failed to demonstrate significantly slower postoperative emptying of solid foods from the small gastric pouch and the distal stomach postoperatively.[7,21,22] None of these studies has, however, found evidence of faster gastric emptying after restrictive surgery, as recorded in this present study following sleeve gastrectomy.

The outcome of the patients after SG in this series is of the utmost importance. Very few patients report vomiting after the small meals that they are now able to consume. Their appetite has been curbed and pre-existing bulimia is only notable by its absence. The rapid gastric emptying and resection of the oregixenic ghre-

lin-producing gastric fundus may partly explain this phenomenon. Furthermore, the distension of the gastric antrum, due to food accumulation in this area after excision of the fundus, may be the dominant mechanism. It reduces hunger and increases the postprandial sensation of satiety with subsequent reduction of food intake.[23] The absence of dumping symptoms in all our patients can be attributed to the fact that the pylorus remains intact. While pre-existing GER symptoms were either treated or significantly improved following SG, some patients developed GER symptoms after SG. Although the improvement in GER is easily explained by the postoperative weight loss, the aggravation or development of GER cannot be as easily explained. It is, however, possible that the surgical division of the ligaments around the abdominal esophagus and destruction of the cardioesophageal junction could be the explanation for this postoperative clinical finding.

In conclusion, clinical and laboratory evidence in patients following sleeve gastrectomy suggests that this bariatric procedure is promising. Rapid emptying of the gastric content into the duodenum and absence of regular vomiting after meals suggest that the term 'restrictive' may not be truly representative of this procedure. Other mechanisms and changes in the entero-hypothalamic axis that can be stimulated by intestinal distension must be sought, to explain the energy intake reduction and the associated weight loss after this 'food limiting' operation.

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