Updated Review of Sleeve Gastrectomy

Nelson Trelles and Michel Gagner*

Department of Surgery, Mount Sinai Medical Center, Miami Beach, FL, USA

Abstract: There is a bariatric explosion worldwide to deal with the rising prevalence of morbid obesity. In 1988, Hess and Hess first added the sleeve gastrectomy (SG) and the duodenal switch (DS) as a modification to the biliopancreatic diversion (BPD) to improve clinical outcomes. But the increased morbidity and mortality observed in super-super-obese patients (BMI > 60 kg/m²) who underwent BPD with DS (BPD-DS) made Gagner and co-workers propose SG as a bridge to gastric bypass or BPD-DS to reduce complications and mortality. The excellent short-term weight-loss outcomes after SG have increased the enthusiasm among surgeons to use it as a definitive treatment for morbidly obese and super-obese patients (BMI > 50 kg/m²). Neurohormonal and gastric emptying changes may account for its superiority over other restrictive procedures. Recent reports on mid-term weight-loss outcomes make this procedure a viable option for bariatric surgeons; nonetheless, long-term studies are still required.

Keywords: Morbid obesity, laparoscopy, sleeve gastrectomy, vertical gastrectomy, greater-curvature gastrectomy, longitudinal gastrectomy, parietal gastrectomy, Magentrasse and Mill procedure, and ghrelin.

INTRODUCTION

We are experiencing an accelerated growth in the practice of bariatric surgery to address the global epidemic of morbid obesity [1-3]. This bariatric explosion is due to the poor results obtained with non-surgical treatments, increasing evidence of significant and durable weight loss with surgery, as well as to a wide diffusion over the media and, consequently, an increased patient demand. This exponential growth is also related to the expansion of laparoscopy in the treatment of morbid obesity. The physiologic and clinical benefits of the laparoscopic bariatric surgery over the open approach [4, 5] have encouraged more primary care physicians to refer morbidly obese patients for surgical treatment, and have motivated more patients to pursue this approach.

The SG, also called greater-curvature, vertical, parietal as well as longitudinal gastrectomy is a new tool in the armamentarium of all bariatric surgeons. In 1988, Hess and Hess (USA) [6] first added the SG, and simultaneously the DS, as a modification to the BPD to improve clinical outcomes. However, in 1993, Marceau (Canada) [7] published the first report on BPD-DS.

Of all the standard restrictive operations, the Magenstrasse and Mill (M & M) procedure most closely resembles the SG. The M & M procedure, first described in Leeds (England) in 1995 [8], is performed using a similar technique to that used for vertical banded gastroplasty (VBG). Major benefits of the M & M procedure include the preservation of the gastric emptying [9], avoidance of foreign materials and reduced gastrointestinal symptoms such as diarrhea, dumping and vomiting [10]. SG is essentially completion of the Magenstrasse distally by completely separating the greater curvature of the stomach from the lesser curvature and the antrum (Fig. **1**).

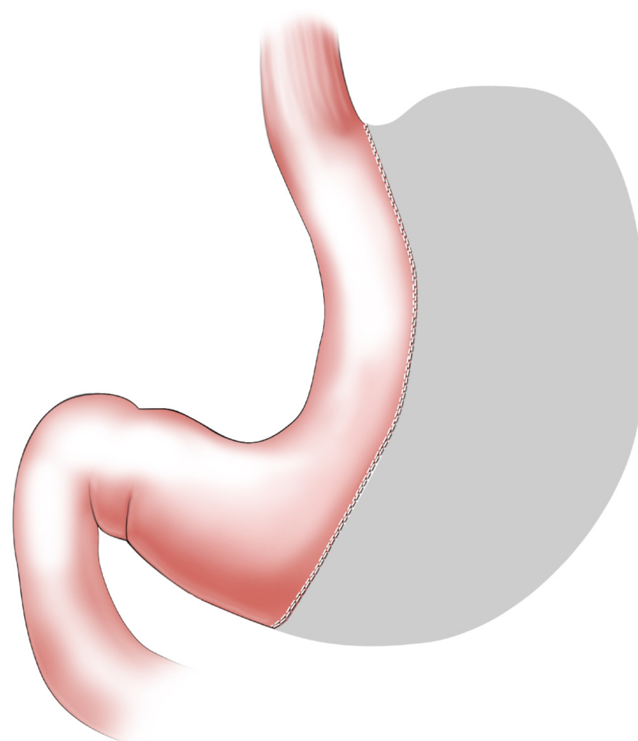

Fig. (1). Sleeve Gastrectomy

Michel Gagner at Mount Sinai Hospital in New York, USA [11, 12] first performed laparoscopic SG (LSG) as the restrictive part of BPD-DS in 1999. However, the initial reports on BPD-DS showed an increased morbidity and mortality in male and super-super-obese patients [13, 14]. To reduce complications and mortality, Gagner and co-workers proposed LSG as the first step of a two-stage laparoscopic BPD-DS (LBPD-DS) in 2000, and later, as the first step of a two-stage laparoscopic roux-en-Y gastric bypass (LRYGB) in 2003 [15]. Since then, the use of SG has been extended

*Address correspondence to this author at the Department of Surgery, Mount Sinai Medical Center, Miami Beach, FL, USA;
E-mail: gagner.michel@gmail.com

worldwide [16-18] due to its major potential benefits, including its technical simplicity and significant weight-loss outcomes with low rate of complications and mortality.

This review describes the technical aspects of SG with the substantial technical variations adopted by different surgical teams, the new established agreements concerning indications for this procedure, the advances in the understanding of the mechanism of action to achieve weight loss, and the short-, mid- and long-term weight-loss outcomes recently published.

MECHANISM OF ACTION OF SLEEVE GASTRECTOMY

Standard restrictive-type operations (VBG, gastric banding and RYGB) results in weight loss through creation of a tiny gastric pouch (10-40 mL) to reduce food intake, and the use of a mechanical outlet reinforcement to delay food passage into the distal stomach, producing energy intake reduction and consequently weight loss. SG was initially conceived as a "purely" restrictive procedure [15, 18] even though it allows a normal eating behaviour that is considered a major advantage for the SG over standard restrictive procedures.

With the discovery of a new hormone: ghrelin [19] and many others adiposity products (leptin and adiponectin) that participate in the regulation of the appetite and weight control, we started to better understand the mechanism of action of SG. Ghrelin is a growth hormone (GH)-releasing peptide, an endogenous ligand for the GH secretagogue receptor, mainly produced by the principal cells of the gastric fundus whose plasmatic concentration regulates meal-time hunger and food intake. Kotidis *et al.* [20] showed that unlike after diet or gastric restrictive surgery, BPD-DS is associated with markedly suppressed ghrelin levels, possibly contributing to the weight-reducing effect of this procedure, being SG the main cause of this reduction. Langer *et al.* [21] showed that ghrelin levels were reduced significantly and constantly after LSG but not after laparoscopic adjustable gastric banding (LAGB). Cohen *et al.* [22] confirmed in a smaller cohort that ghrelin levels are reduced (-23.3%) in super-super-obese patients after LSG while a significant increase was observed after LAGB (+14%). These results suggested that LSG might have a physiological advantage to achieve sustained weight loss over other restrictive procedures that do not decrease ghrelin levels because they do not influence the ghrelin-producing cell mass. However, food intake restriction and ghrelin levels are not the only mechanisms to understand how SG works to achieve weight loss. Hould *et al.* [23] reported a hastened gastric emptying in patients who underwent BPD-DS as compared to controls and BPD. Recently, Melissas *et al.* [24] reported the results of antrum functionality in patients who underwent SG. Those results have added some important details to the mechanism involved in SG to achieve weight loss. Melissas and co-workers have shown that following SG, gastric emptying is faster as compared to the preoperative state, and symptoms of vomiting after eating are either absent or very mild. Although meal size was drastically reduced, meal frequency increased. All these findings suggest that the term restrictive does not completely describe the intricate mechanism of SG.

At present, we believe that SG achieves weight loss by at least two mechanisms: (1) the decreased volume of the gastric reservoir, the preservation of the antropyloric pump and the vagal enervation contribute to enhance early satiety; (2) it reduces plasma ghrelin levels.

The preservation of the antrum may enhance early satiety due to antrum distension after food intake. Furthermore, the accelerated pump function of the antrum could also be an important factor as the non-digested food passes rapidly through the duodenum (reduced intestinal transit time), probably enhancing malabsorption as first suggested by Marceau [7].

More research studies on other mechanism of energy intake reduction are still pending to precisely understand how this "purely" restrictive procedure achieves weight loss.

INDICATIONS AND CONTRAINDICATIONS

Anticipated weight loss, relief of co-morbidities, improved quality of life, patient preference, technical considerations and risks, patient behaviour and body composition changes [25] are main factors that should be taken into account when selecting a bariatric procedure.

From the first International Consensus Summit for SG (October, 2007. New York, USA) that brought together the most important bariatric surgeons worldwide, many important agreements were established in controversial issues based on recent reported data concerning new applications for SG. From this consensus, current accepted indications for this procedure are:

- In super-super-obese patients (BMI > 60 kg/m²), as a bridge or first stage of a two-staged definitive procedure (RYGB or BPD-DS)
- In super-obese (BMI > 50 kg/m²) patients, as a definitive procedure or as a first stage of RYGB or BPD-DS
- In patients with BMI > 40 kg/m² with severe medical disease (cirrhosis, pulmonary hypertension, cardiac failure)
- In patients with low BMI (35-40 kg/m²) with or without a major co-morbidity, as a better alternative than LAGB, when patients are concerned about the presence of a foreign material or for those who may not be compliant with frequent follow-up and adjustments
- The morbidly obese adolescent and elderly
- An excellent alternative in patients with inflammatory bowel disease, severe small bowel adhesions or those patients who underwent previous colectomy in whom RYGB or BPD-DS could put them at risk for increased diarrhea or anastomotic leaks, or in renal failure patients in whom intestinal bypass is contraindicated
- In patients who require periodic gastric surveillance (e.g., *Helicobacter pylori* infection, gastritis, ulcers, neoplasm, and intestinal metaplasia) because the stomach remains accessible *via* upper endoscopy, contrary to RYGB, and also due to the reduction of the gastric tissue

- In patients with anemia, those requiring anti-inflammatory medications, those who use high doses of steroids (e.g. in severe asthma or organ transplant candidates or recipients), and those who use cardiac or transplant medication
- As a measure to allow other procedures to be performed (e.g. joint replacement)
- As a revisional surgery, in patients who experience complications, inadequate weight loss or poor quality of life after LAGB, RYGB or VBG

Absolute contraindications to sleeve gastrectomy, and to any bariatric procedure, are:

- Mental/cognitive impairment
- Advanced neoplasia
- Unstable coronary artery disease

At present, age is no longer an absolute contraindication to any bariatric surgery [26, 27].

Benefits of SG include low rate of complications, the avoidance of foreign bodies (no erosion, infection or revision of reservoir and no adjustments), the maintenance of normal gastrointestinal continuity (no anastomoses) with preservation of antrum and a nerve supply permitting a faster than normal gastric emptying, the absence of a malabsorptive tool (intestinal bypass), a relatively short operative time and the ability to convert this procedure into multiple other operations if the weight loss is inadequate. As well, dumping syndrome does not develop because the pylorus is preserved, and the incidence of peptic ulcers is minimized. The absence of an intestinal bypass as seen in RYGB and BPD-DS eliminates the risk of intestinal obstruction, vitamin deficiencies, anemia, osteoporosis and protein malnutrition.

Disadvantages are related to its main source of complication: the staple line where leaks and bleeding can develop. Theoretically, weight regain is more likely due to the absence of the intestinal bypass.

TECHNICAL ASPECTS OF SLEEVE GASTRECTOMY

After prophylactic antibiotics and general anaesthesia are administered, the patient is placed in the supine split-leg position and reverse Trendelenburg with assurance of proper support for the extremities to prevent falls during position changes of the operating table (Fig. **2**).

Unlike other surgical teams, we perform the SG through 7 abdominal trocars to facilitate exposure and dissection of the stomach (Fig. **3**).

Two basic different techniques have been described to perform LSG. The first technique starts with the stapling of the stomach as soon as the surgeon accesses to the lesser sac, then the greater curvature devascularization is performed after completion of the sleeve gastrectomy. We prefer the second technique in which stapling is performed after complete devascularization of the greater curvature.

We start by dividing the greater omentum with the ultrasonic shears (SonoSurg, Olympus Corporation, Tokyo, Japan) at a midpoint along the greater curvature (Fig. **4**). The

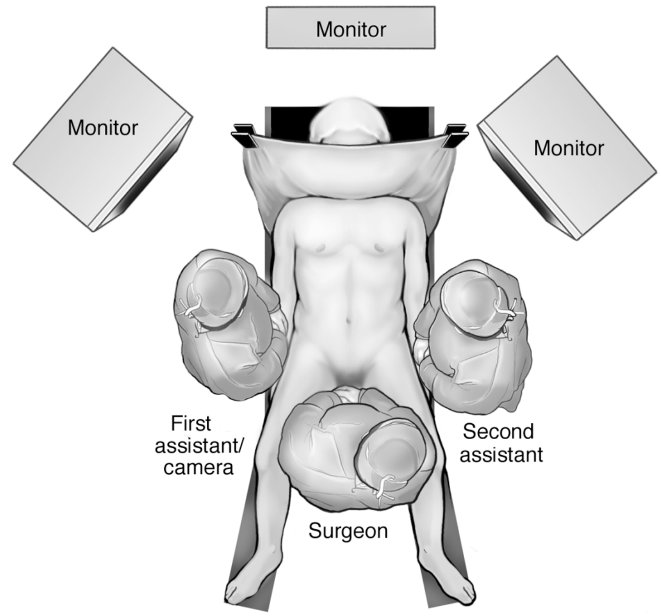

Fig. (2). Supine split-leg position (French position).

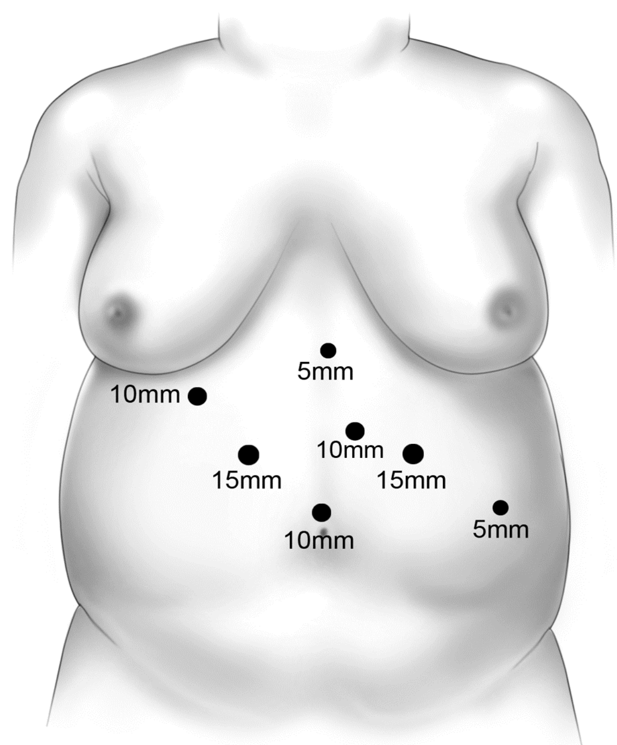

Fig. (3). SG is performed using 7 trocars.

branches of the gastroepiploic artery are divided near the gastric wall. We continue cephalad and then proceed with division of the short gastric vessels that is carried out up to the fundus.

Division of the posterior fundic vessels is also performed. The angle of *His* is then dissected free from the left crus of the diaphragm. Careful attention on dissection must be taken due to the risk of splenic or esophageal injury.

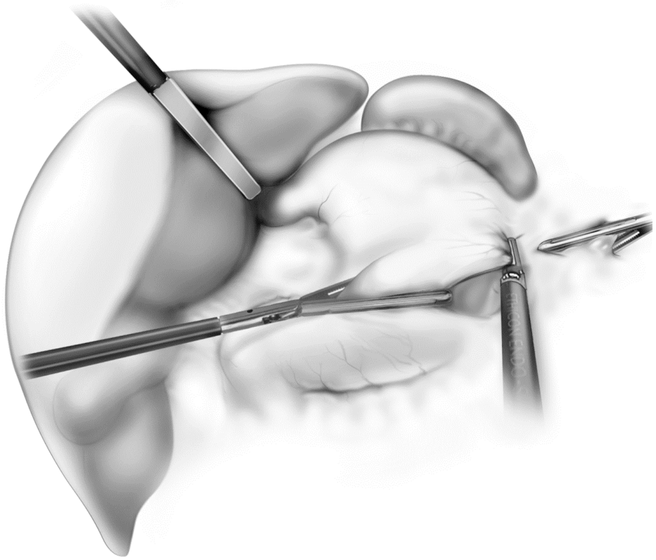

Fig. (4). Greater curvature dissection.

The greater curvature dissection continues from the midpoint distally to approximately 2 cm proximal to the pylorus. After the greater curvature dissection is complete, we proceed to lyse all adhesions in the lesser sac leaving the posterior aspect of the antrum free. The entire greater curvature devascularization can also be performed starting at the level of the left crus and then going caudal 2 cm proximal or distal to the pylorus (according to the surgeon's discretion in antrum preservation); or starting 2 cm distal or proximal to the pylorus (again, depending on antrum preservation) and then going cephalad up to the fundus.

We advocate antrum preservation, thus, at approximately 5-6 cm proximal to the pylorus (Fig. **5**), the SG begins with sequential firings of 60-mm/4.8-mm linear staplers, reinforced with buttressing material to decrease blood loss from the staple line. Even though the use of buttressing material increases costs, its use reduces the operative time. We use the bioabsorbable glycolide copolymer reinforcements (Seamguard W.L. Gore & Associates, Inc, Flagstaff, AZ, USA) because they have shown to be safe and effective in preventing intra-operative bleeding; however, not enough data is available to demonstrate a decreased rate of leakage (cohort too small) [28-33].

The distance from the pylorus where the division of the stomach starts is not standard. We still do not know how much antrum we should preserve in order to obtain better results in terms of weight loss. In Spain, Baltasar *et al.* [18] advocate resection of the antrum by completing the greater curvature dissection distal to the pylorus so that the firing can start 2 cm proximal to the pylorus with the linear stapler positioned toward the *incisura angularis* and close to a 32-Fr bougie that follows the lesser curvature, or firing 3-4 cm proximal to the pylorus in BPD-DS.

The first two stapler firings can be done using either a 60-mm or a 45-mm linear stapler loaded with green (4.8-mm staple height) or blue cartridge (3.5-mm staple height), depending on an assessment of the thickness of the stomach wall. Following this, the use of 60-mm, blue linear staplers to complete the gastrectomy is standard. However, Crookes *et al.* [16] advocate the use of 75-mm linear staplers for the entire gastrectomy.

We position the first stapler so that a narrow 1.5 cm of anterior stomach serosa is visible between the stapler and the lesser curvature. A second 60-mm/4.8-mm linear stapler is aligned with the first and then fired, leaving enough width not to occlude the gastric lumen. After the second firing, a bougie is inserted transorally by the anesthesiologist and carefully positioned in the antrum under laparoscopic vision. Unlike other surgical teams who introduce the bougie into the stomach once the greater curvature dissection is complete, inserting the bougie after the first two stapler firings is a technical advantage for facilitating the alignment of the bougie along the lesser curvature in order to proceed with the SG.

For all LSG as part of a BPD-DS, we use the 60-Fr bougie that allows the surgeon to create a gastric pouch size of 150 to 200 mL that ensures an adequate protein intake. For independent LSG we use a 40-Fr bougie, but it could be smaller or greater (28-54 Fr). After the first two stapler firings, usually three additional 60-mm/3.5- or 4.8-mm stapler firings, parallel to the bougie, are needed to complete the gastrectomy. At the uppermost portion of the stomach, the transection line is allowed to deviate away from the bougie to avoid severe stenosis at the gastroesophageal junction but going further from the bougie may lead to fundus dilatation and weight regain. Our experience has shown that most of the gastric dilatation comes from this technical step of the gastrectomy so careful attention must be taken when performing this step.

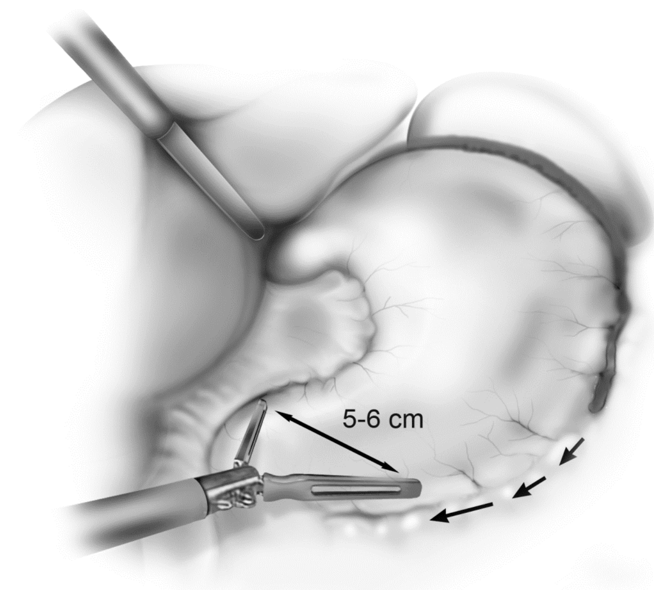

Fig. (5). Selecting the point in the antrum where the stapler firing will start.

The gastric pouch size usually varies from 60 to 120 mL (Fig. **6**). Consensus about the volume of the sleeve gastrectomy, which is related to the bougie size used as a guide for the gastric transection, is still pending. Our rationale for using different bougie sizes in SG, as an independent procedure or as part of BPD-DS, is that patients undergoing BPD-DS are more prone to protein deficiencies, so by leaving a larger reservoir we avoid nutritional deficiencies - in particular, protein malnutrition.

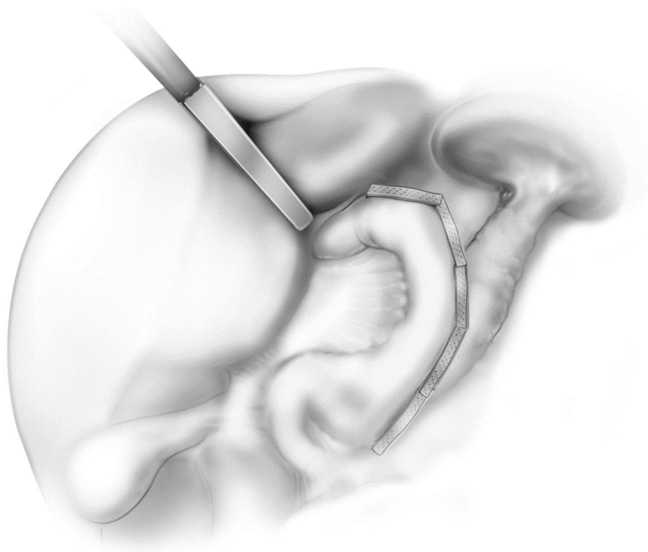

Fig. (6). Final appearance of the stomach after completion of the SG.

Following completion of the SG, the anesthesiologist removes the bougie. We place interrupted figure-of-eight/of 3-0 Maxon sutures at the intersections of the staple lines and at the most distal end of the staple line as we consider this to be the level where most leaks occur. Surgeons who do not use buttressing materials usually advocate over-sewing the staple line with an absorbable running suture (silk, Vicryl, PDS or Maxon) with or without inversion of the staple line to prevent bleeding or leaks. We should note that the sutures must be absorbable for two reasons, (1) to avoid the narrowing of the gastric tube (permanent stricture) due to excessive cicatrisation produced by the non-absorbable material, and (2) to avoid gastric ulcers or intraluminal migration of stitches. Some surgical teams advocate the fixation of the greater omentum to the staple line in an effort to prevent bleeding and leaks, as well as to keep the stomach in the correct position to avoid coiling of the gastric tube [34].

Once the gastrectomy is completed and the appropriate measures are taken to prevent bleeding and leaks, the excised stomach is retrieved through the umbilicus using a large specimen, plastic impermeable bag (Tyco Healthcare, Norwalk, Conn.) to prevent wound contamination. It can also be retrieved through the enlarged left 15-mm port incision, however, by doing so we can stretch the muscular layer of the abdominal wall contributing to increased postoperative pain.

Finally, we perform a methylene-blue-test, through an orogastric tube, with the proximal duodenum clamped with a long intestinal forceps to test the staple line for leaks and measure the gastric capacity. Over-sewing is used if leaks are identified. We do not perform routine liver biopsy, cholecystectomy or drainage.

POSTOPERATIVE FOLLOW-UP

Patients are cared for on the ward unless significant pre-existing cardiopulmonary disease, male gender, BMI > 60 kg/m², diabetes, obstructive sleep apnea (OSA) and intraoperative complications warrant ICU care [35]. In patients with OSA, we reinstitute the CPAP or BiPAP treatment in the recovery room and continue during day- and night-time sleep in the immediate postoperative period. Despite the fact that guidelines for DVT prophylaxis in obese patients have not yet been developed, 95% of surgeons use some form of DVT prophylaxis. We do not use heparin (in any form) at least patients have had any venous thromboembolic event in the past or have other documented risk factor (other than obesity) for DVT. We use sequential compressive boots perioperatively, and strongly encourage patients for early ambulation after surgery. We perform an upper gastrointestinal contrast study selectively when clinical suspicion of leaks exists. Patients are usually discharged on the second postoperative day. The follow-up schedule and postoperative dietary surveillance and measures vary depending on the center. We do not use proton pump inhibitors systematically, only for patients with dysphagia or reflux symptoms. Patients with intact gallbladder are prescribed Ursodiol 600 mg daily (Actigall, Ciba-Geigy, Summit, N.J.) for 6 months during the time of maximal weight loss for gallstone prophylaxis [36].

WEIGHT-LOSS OUTCOMES

One-stage bariatric procedures in the male and super-super-obese patient are associated with increased serious morbidity, mortality and long-term weight loss failure [13, 14]. In 2003, Gagner *et al.* [15] reported the results of LSG, as the first step of a two-stage LRYGB, after obtaining satisfactory results with a two-stage LBPD-DS, to decrease morbidity and mortality in this high-risk group of morbidly obese patients. In this study, 7 patients (3 females and 4 males; mean age 43 years) with BMI between 58 to 71 kg/m² underwent a two-stage LRYGB. Prior to the LSG, the mean BMI was 63 kg/m² and prior to the second-stage procedure, BMI was 50 kg/m² with 33% EWL. Mean time between procedures was 11 months. There were 3 complications in 2 patients and no mortalities were reported after LSG. Since that initial study, many reports on SG have been published [16-18, 21, 37-51].

Langer *et al.* [21] showed that LSG is more effective than LAGB in a prospective study of 20 patients. Another prospective but randomized trial comparing LSG with LAGB reported better results in terms of weight loss for LSG [42]. In this report, 40 patients were randomly assigned to each group. Median age was 40 years for the LSG group and 36 years for the LAGB group. Preoperative median BMI was 39 kg/m² for LSG and 37 kg/m² for LAGB. No statistical differences were reported in gender, age distribution and preoperative BMI. Median %EWL at 1 year was 57.7% after LSG and 41.4% after LGB ($p = 0.0004$); and at 3 years, median %EWL was 66% versus 48% ($p = 0.0025$), respectively. Loss of appetite after 1 year was reported in 75% for the LSG group and 42.5% for the LAGB group ($p = 0.003$), and after 3 years in 46.7% of patients with LSG and 2.9% of patients with LAGB ($p = 0.0001$). These results demonstrated that LSG is more effective than LAGB after 1 and 3 years. More recently, Lee *et al.* [46] reported the results of 216 patients who underwent LSG. Mean age was 44.7 years and mean preoperative BMI was 49 kg/m², with 36 (16.6%) super-super-obese patients. Complications occurred in 16 (7.4%) patients and no mortality was reported. Leaks occurred in 3 (1.4%) patients. A comparison of LSG to LAGB, to LRYGB and to LBPD-DS showed shorter operative time for LSG than for the LRYGB and LBPD-DS. However, the operative time for the LAGB is not significantly different from the LSG. Even though LSG patients were more obese than LRYGB an LBPD-DS patients, and a greater percentage of LSG patients were males (males accumulate more intra-abdominal fat making the procedure more technically difficult), they lost more weight at 1 year (129 ± 51 lbs) than with LAGB and LRYGB patients (58 ± 27 and 110 ± 37 lbs, respectively, $p < .01$). The LSG weight loss at 1 year was comparable to the weight loss achieved after LBPD-DS (120 ± 24 lbs). Therefore, LSG is superior to standard restrictive procedures and has comparable weight loss results in the short term with LRYGB and LBPD-DS with low morbidity and mortality.

LSG also represents an excellent option for super-obese patients. Hamoui *et al.* [45] reported the results of a case series of 118 patients with a median age of 47 years and a median BMI of 55 kg/m², with 73% of patients having a BMI > 50 kg/m². They performed 115 open SG and 3 LSG. The morbidity was 15.3% (18 patients) and mortality 0.85% (1 perioperative death). Median %EWL was 37.8% at 6 months, 49.4% at 12 months and 47.3% at 24 months. Six patients requested conversion to BPD-DS during the follow-up period. These results showed that LSG is a safe and effective procedure in super-obese patients and can be used either as an independent operation or as a bridge procedure. Moreover, LSG has also proved to be more effective than gastric balloon as a first-stage procedure in super-obese patients [37]. Almogy *et al.* [16] and Mognol *et al.* [17] also described LSG as an independent procedure for super-obese patients with satisfactory results (Table **1**).

Given the effectiveness of LSG in super-super-obese and super-obese patients, Langer *et al.* [40] reported the results of LSG in morbidly obese patients. A total of 23 patients (8 super-obese and 15 with a BMI < 50 kg/m²) were included in the prospective study. Mean age was 41.2 years (17 females and 6 males) and mean BMI was 48.5 kg/m². Mean %EWL was 46% at 6 months, 56% at 12 months and 57% at 18 months (in 15 patients). In comparing %EWL in super-obese and morbidly obese patients, no significant differences were found at 6 and 12 months after LSG. Thus, LSG also proved to be effective when BMI < 50 kg/m². Moreover, Lee *et al.* [46] also showed that patients with BMI < 50 kg/m² rapidly achieved a BMI < 35 kg/m² at 6 months, supporting the more accepted trend of using LSG in patients with low BMI.

During the first international consensus summit for SG (2007, USA), Dr. Won Woo Kim reported his 3 years experience in 83 patients from Korea who underwent LSG using a 48-Fr bougie (50 - 60 mL gastric tube). Mean %EWL, calculated by bio-impedance analysis, was 88.8% at 1 year, 87% at 2 years and 84.3% at 3 years after surgery. Excess BMI loss (EBMIL) was 74.1% at 1 year, 71.4% at 2 years and 68.7% at 3 years. Two major complications were reported (1 leak and 1 delayed bleeding). Despite differences in cultural backgrounds (e.g., dietary habits, life style), the body fat distribution between Asian and Western patients, and the severity of obesity between these populations, the results at 3 years after surgery demonstrate the mid-term efficacy of the LSG.

Recently, Weiner *et al.* [47] reported the results of 120 patients who underwent LSG, which were performed without calibration or using a 32-Fr or a 44-Fr bougie. All three groups were comparable for age, gender and co-morbidities. Only 37 and 22 patients completed their follow-up visit at 3 and 4 years, respectively, including patients without calibration and patients within the 44-Fr group. Only 8 patients with a non-calibrated sleeve completed the 5-year follow-up visit. Mean EBMIL was 62% at 1 year and maximum EBMIL was 64% at 2 years in morbidly obese and super-obese patients. Despite offering satisfactory weight loss in the short-term for all 3 groups, LSG is associated with weight regain after the third year depending on the size of the sleeve. It appears that over time, patients without calibration tend to regain weight but patients with the sleeve performed with the 44-Fr bougie still lose weight after 4 years.

A comprehensive review of all English literature on SG, including 1163 patients, shows a mean %EWL after SG ranging from 35% to 71.6% at 6 months, 45% to 83% at 1 year, 47% to 83% at 2 years and 66% at 3 years (Table **1**). Five deaths (3 deaths within 1 month after surgery) were reported in the literature (0.4%) and the morbidity was significantly low in larger cohorts with the highest rates of complications observed in the smallest series.

DISCUSSION

The concept that the SG is a "purely" restrictive procedure is gradually changing. At present, we accept that the significant reduction of large parts of the ghrelin-producing stomach mass and changes in gastric emptying may account for its superiority to other restrictive procedures in terms of weight loss and sustained decrease of hunger.

Marceau *et al.* [7] suggested in 1998 that SG might have been a significant factor in helping to lose excess weight for patients who underwent BPD-DS, even though they had a longer common channel than those who had a BPD. This initial suggestion emphasized the potential role of SG in the surgical management of obesity. At present, LSG is now being performed more frequently given the satisfactory weight-loss results not only in the short-term, but also in the mid-term with shorter operating times and no need to create anastomoses. Most of patients with BMI > 60 kg/m² or with unfavourable anatomy now undergo SG as a bridge to a more definitive procedure usually after 6-12 months when BMI drops significantly (< 50 kg/m²) or weight loss plateaus and co-morbidities improve. It can usually be performed by laparoscopy even in patients weighing over 500 lbs. It also allows surgeons to assess whether patients will be compliant in a stricter nutritional regime and surgical follow-up if they opt to do a second stage procedure.

LSG has demonstrated weight-loss results comparable to LRYGB and LBPD-DS but with a lower morbidity profile, associated with improvement of health status and resolution of co-morbidities such as diabetes, hypertension, OSA and dyslipidemia [16, 18, 38, 41, 44, 45, 47, 48]. Silecchia *et al.* [44] showed that in 41 super-obese patients (9 patients with BMI > 60 kg/m²) following LSG, 60% of major co-morbidities were resolved and 24% improved, 57.8% of patients were co-morbidity-free and 31.5% had only one major co-morbidity. Also, they showed a reduction in the operative risk (ASA score) after LSG. They proved that LSG effec-

Table 1. Published Series on Sleeve Gastrectomy

Study	Pat (n)	Preop BMI	Follow-Up (Months)	% EWL 6/12 Months	Morb Rate (%)	Mort Rate (%)	Weight Regain (%)	Resolution of Co-Morbidities (%)
Lalor *et al.* (2008) [51]	148	44	6	53/NR	2.9%	0	NR	NR
Givon-Madhala *et al.* (2007) [50]	25	44	4	NR Φ	0	0	NR	NR
Dapri *et al.* (2007) [49]	40 (20/20)	42.5/47	12	43.4-42.2/ 48.3-49.5	20/10	0	NR	NR
Braghetto *et al.* (2007) [48]	50 Ω	37.9	12	NR £	16	0	NR	HTN (57) DM (100)
Weiner *et al.* (2007) [47]	120	60.7	60	NR Δ	17.5	0.8	13.3	HTN (42) DM (14)
Lee *et al.* (2007) [46]	216	49	24	83▲	7.4	0	4.2	NR
Melissas *et al.* (2007) [24]	23	47.2	12	NR φ	21.7	0	NR	NR
Hamoui *et al.* (2006) [45]	118	55	24	47.3 α	15.3	0.85	5	DM (47) HTN (15)
Silecchia *et al.* (2006) [44]	41	57.3	12	NR ξ	12.1	0	NR	DM (79.6) HTN (62.5)
Roa *et al.* (2006) [43]	30	41.4	6	52.8/NR	13.3	0	NR	NR
Himpens *et al.* (2006) [42]	40	39	36	66 Ψ	5	0	5	NR
Cottam *et al.* (2006) [41]	126	65.3	12	NR/46	14	0.8	NR	HTN (78) DM (81)
Langer *et al.* (2006) [40]	23	48.5	20	46/56	NR	NR	13	NR
Catheline *et al.* (2006) [39]	4	65	6	40/NR	25	0	0	NR
Han *et al.* (2005) [38]	60	37.2	12	71.6/83.3	3.8 ⊥	0.7 ⊥	NR	HTA (92.9) DM (100)
Milone *et al.* (2005) [37]	20	69	6	35/NR	5	0	NR	NR
Langer *et al.* (2005) [21]	10	48.3	6	61/NR	0	0	NR	NR
Baltazar *et al.* ♠ (2005) [18]	7 7 16	61-74 >40 35-43	4-27 4-16 3-27	56.1 33.6-90 62.3	6.7	3.3	NR	HTN (100) DM (100)
Mognol *et al.* (2005) [17]	10	64	12	NR/51	0	0	NR	NR
Almogy *et al.* (2004) [16]	21	57.5	17.5	NR/45.1	23.8	0	NR	(38.1) for HTA, DM and CHF
Regan *et al.* (2003) [15]	7	63	11	NR/33	42.8	0	0	NR
TOTAL: 21 studies	1163	35-74	4-60	33-83	0-42.8	0.4 (5/1163)	0-13.3	

HTA: hypertension; DM: diabetes mellitus; NR: not reported; and CHF: congestive heart failure.
Φ: %EBMIL was 49% at 4 months.
Ω: follow-up data through 6 months and 12 months were available for 25 and 18 patients, respectively.
£: % EBMIL was 79% and 85% at 6 and 12 months, respectively.
Δ: %EBMIL was 62% at 1 year; %EBMIL was 64% at 2 years.
▲: median %EWL was 59% at 1 year.
φ: %EBMIL was 54.1% at 6 months and 72.5% at 12 months in morbidly obese and super-obese patients.
α: %EWL was 37.8% at 6 months and 49.4% at 12 months.
ξ: mean BMI was 44.5 and 40.8 at 6 and 12 months, respectively.
Ψ: median %EWL at 1 year was 57.7%.
⊥: a total of 130 patients were used to calculate rates.
♠: 1 patient with BMI 28 underwent LSG after LAGB to improve quality of life; EBMIL was 13% at 1 year.

tively downstages patients to a lower-risk group as Cottam *et al.* [41] and Weiner *et al.* [47] also reported, and effectively resolved or improved co-morbidities as many other teams have also demonstrated (Table **1**).

The most frequent perioperative complications observed after LSG are: leaks, bleeding (from different sources including the staple line and trocar site) and pulmonary complications, including pulmonary embolism, pneumonia, atelectasis and prolonged ventilator requirements. Gastroesophageal reflux disease (GERD) and strictures are late complications observed after LSG. Himpens *et al.* [42] showed that GERD appears de novo in 23% of patients at 1 year but decreases to 3.1% at 3 years after LSG. They showed that GERD is more frequent at 1 year after LSG, but more frequent following

LAGB after 3 years. Despite GERD is an issue of concern, it is possible to perform a successful laparoscopic hiatal hernia repair during or after LSG [34, 49, 52]. If the lower esophageal sphincter is incompetent, endoluminal techniques might be required because inadequate gastric tissue will be available for fundoplication.

Even though the rate of complications after SG is low, the severity of complications seems to be a problem. Leaks and bleeding represent the most feared complications and the most frequently reported causes of death after LSG. Reported leak rates range from 0.7 to 5.3% [24, 41, 44-46, 50]. Esophageal stenting (endoluminal technique) is an effective and new strategy for treatment of gastric fistula, and may be performed safely in a patient with leak of the staple line following sleeve or re-sleeve gastrectomy (for weight regain) with or without BPD-DS [53, 54]. Baltazar *et al.* [55] has recently proposed the creation of a Roux limb to treat leaks after SG with satisfactory results.

The main concern of the LSG is the possibility of dilatation of the gastric reservoir with consequent weight regain. This is not a concern limited to the short-term but to the mid- and long-term. However, laparoscopic re-sleeve gastrectomy (LRSG) can be performed in the context of a gastric tube dilatation, inadequate original gastric volume reduction or in case of poor weight loss after independent LSG or LBPD-DS [47, 56, 57]. Furthermore, LSG can also be converted to LRYGB or LBPD-DS in case of weight regain. By performing LRSG in BPD-DS patients, as opposed to changing limbs and shortening the common channel, we can obtain a reduction on average of 7-10 kg/m² of BMI [56]. Consumption of soft calories should also be avoided to prevent inadequate weight loss or weight regain.

In an effort to prevent gastric dilatation in the long term and with the rationale to obtain better weight-loss outcomes, surgeons tend to use the smallest bougie size to perform the SG. Weiner *et al.* [47] suggest in a prospective but non-randomized study that the volume of the gastric sleeve is an important factor for later dilatation and consequently weight regain. The non-calibrated sleeves showed satisfactory short-term weight loss comparable to the calibrated sleeves, but over time patients regain weight. However, calibrated sleeves still lose weight over time. They also found that a removed gastric volume of < 500 mL seems to be a predictor of weight loss failure or early weight regain.

Even though short-term and mid-term weight-loss outcomes after LSG are satisfactory, longer-term, larger, and even randomized studies are still required to determine the efficacy of LSG over time and whether the weight-loss outcome after LSG is influenced by the calibre of the bougie used to create the sleeve.

CONCLUSIONS

LSG represents a safe and effective procedure to achieve significant weight loss, as well as significant improvement or resolution of major obesity-related co-morbidities, with a low morbidity and mortality profile.

LSG represents the preferred surgical option in super-super-obese patients who may benefit from a two-stage LRYGB or LBPD-DS. However, it is also effective in super-obese patients and in patients with BMI < 50 kg/m² as a stand-alone surgery or as a bridge to a more definitive procedure.

Even though LSG has shown satisfactory clinical outcomes in the short- and mid-term, long-term data is still required to establish differences over time.

REFERENCES

[1] Pope GD, Birkmeyer JD, Finlayson SRG. National trends in utilization and in–hospital outcomes of bariatric surgery. J Gastrointest Surg 2002; 6(6): 855-60; discussion 861.

[2] Nguyen NT, Root J, Zainabadi K, *et al.* Accelerated growth of bariatric surgery with the introduction of minimally invasive surgery. Arch Surg 2005; 140(12): 1198-202; discussion 1203.

[3] Davis MM, Slish K, Chao C, Cabana MD. National trends in bariatric surgery, 1996-2002. Arch Surg 2006; 141(1): 71-74; discussion 75.

[4] Nguyen NT, Goldman C, Rosenquist CJ, *et al.* Laparoscopic versus open gastric bypass: a randomized study of outcomes, quality of life, and costs. Ann Surg 2001; 234(3): 279-289; discussion 289-91.

[5] Luján JA, Frutos MD, Hernández Q, *et al.* Laparoscopic versus open gastric bypass in the treatment of morbid obesity: a randomized prospective study. Ann Surg 2004; 239(4): 433-37.

[6] Hess DS, Hess DW. Biliopancreatic diversion with a duodenal switch. Obes Surg 1998; 8(3): 267-82.

[7] Marceau P, Hould FS, Simard S, *et al.* Biliopancreatic diversion with duodenal switch. World J Surg 1998; 22(9): 947-54.

[8] Johnston D, Dachtler J, Sue-Ling HM, King RF, Martin G. The Magenstrasse and Mill operation for morbid obesity. Obes Surg 2003; 13(1): 10-16.

[9] Carmichael AR, Johnston D, Barker MC, Bury RF, Boyce J, Sue-Ling H. Gastric emptying after a new, more physiological anti-obesity operation: The Magenstrasse and Mill procedure. Eur J Nucl Med 2001; 28(9): 1379-83.

[10] Carmichael AR, Sue-Ling HM, Johnston D. Quality of life after the Magenstrasse and Mill procedure for morbid obesity. Obes Surg 2001; 11(6): 708-15.

[11] de Csepel J, Burpee S, Jossart G, *et al.* Laparoscopic biliopancreatic diversion with a duodenal switch for morbid obesity: a feasibility study in pigs. J Laparoendosc Adv Surg Tech A 2001; 11(2): 79-83.

[12] Gagner M, Patterson E. Laparoscopic biliopancreatic diversion with duodenal switch. Dig Surg 2000; 17: 547-566.

[13] Ren CJ, Patterson E, Gagner M. Early results of laparoscopic biliopancreatic diversion with duodenal switch: a case series of 40 consecutive patients. Obes Surg 2000; 10(6): 514-523; discussion 524.

[14] Fazylov RM, Savel RH, Horovitz JH, *et al.* Association of super-super-obesity and male gender with elevated mortality in patients undergoing the duodenal switch procedure. Obes Surg 2005; 15(5): 618-23.

[15] Regan JP, Inabnet WB, Gagner M, Pomp A. Early experience with two-stage laparoscopic Roux-en-Y gastric bypass as an alternative in the super-super obese patient. Obes Surg 2003; 13(6): 861-64.

[16] Almogy G, Crookes PF, Anthone GJ. Longitudinal gastrectomy as a treatment for the high-risk super-obese patient. Obes Surg 2004; 14(4): 492-97.

[17] Mognol P, Chosidow D, Marmuse JP. Laparoscopic sleeve gastrectomy as an initial bariatric operation for high-risk patients: initial results in 10 patients. Obes Surg 2005; 15(7): 1030-33.

[18] Baltasar A, Serra C, Pérez N, Bou R, Bengochea M, Ferri L. Laparoscopic sleeve gastrectomy: a multi-purpose bariatric operation. Obes Surg 2005; 15(8): 1124-28.

[19] Kojima M, Hosoda H, Date Y, Nakasato M, Matsuo H, Kangawa K. Ghrelin is a growth-hormone-releasing acylated peptide from stomach. Nature 1999; 402 (6762): 656-60.

[20] Kotidis E, Koliakos G, Baltzopoulos VG, Ioannidis KN, Yovos JG, Papavramidis ST. Serum ghrelin, leptin and adiponectin levels before and after weight loss: comparison of three methods of treatment- a prospective study. Obes Surg 2006; 16 (11): 1425-32.

[21] Langer FB, Reza Hoda MA, Bohdjalian A, *et al.* Sleeve gastrectomy and gastric banding: effects on plasma ghrelin levels. Obes Surg 2005; 15 (7): 1024-29.

[22] Cohen R, Uzzan B, Bihan H, Khochtali I, Reach G, Catheline JM. Ghrelin levels and sleeve gastrectomy in super-super-obesity. Obes Surg 2005; 15 (7): 1501-02.
[23] Hould FS, Lagacé M, Marceau P, Potvin M, Bourque RA, Biron S. Hastened gastric emptying after parietal gastrectomy and duodenal switch. Obes Surg 1996; 6 (2): 121.
[24] Melissas J, Koukouraki S, Askoxylakis J, *et al*. Sleeve gastrectomy: a restrictive procedure? Obes Surg 2007; 17 (1): 57-62.
[25] Strain GW, Gagner M, Inabnet WB, Dakin G, Pomp A. Comparison of effects of gastric bypass and biliopancreatic diversion with duodenal switch on weight loss and body composition 1-2 years after surgery. Surg Obes Relat Dis 2007; 3 (1): 31-36.
[26] Nelson LG, Lopez PP, Haines K, *et al*. Outcomes of bariatric surgery in patients > or = 65 years. Surg Obes Relat Dis 2006; 2 (3): 384-88.
[27] Murr MM, Siadati MR, Sarr MG. Results of bariatric surgery for morbid obesity in patients older than 50 years. Obes Surg 1995; 5 (4): 399-402.
[28] Consten EC, Gagner M. Staple-line reinforcement techniques with different buttressing materials used for laparoscopic gastrointestinal surgery: a new strategy to diminish perioperative complications. Surg Technol Int 2004; 13: 59-63.
[29] Yo LS, Consten EC, Quarles van Ufford HM, Gooszen HG, Gagner M. Buttressing of the staple line in gastrointestinal anastomoses: overview of new technology designed to reduce perioperative complications. Dig Surg 2006; 23(5-6): 283-91.
[30] Nguyen NT, Longoria M, Chalifoux S, Wilson SE. Bioabsorbable staple line reinforcement for laparoscopic gastrointestinal surgery. Surg Technol Int 2005; 14: 107-11.
[31] Nguyen NT, Longoria M, Welbourne S, Sabio A, Wilson SE. Glycolide copolymer staple-line reinforcement reduces staple site bleeding during laparoscopic gastric bypass: a prospective randomized trial. Arch Surg 2005; 140(8): 773-78.
[32] Consten EC, Gagner M, Pomp A, Inabnet WB. Decreased bleeding after laparoscopic sleeve gastrectomy with or without duodenal switch for morbid obesity using a stapled buttressed absorbable polymer membrane. Obes Surg 2004; 14 (10): 1360-66.
[33] Consten EC, Dakin GF, Gagner M. Intraluminal migration of bovine pericardial strips used to reinforce the gastric staple-line in laparoscopic bariatric surgery. Obes Surg 2004; 14 (4): 549-54.
[34] Santoro, S. Technical aspects in sleeve gastrectomy. Obes Surg 2007; 17: 1534-35.
[35] Pieracci FM, Barie PS, Pomp A. Critical care of the bariatric patient. Crit Care Med 2006; 34 (6): 1796-804.
[36] Sugerman HJ, Brewer WH, Shiffman ML, *et al*. A multicenter, placebo-controlled, randomized, double-blind, prospective trial of prophylactic ursodiol for the prevention of gallstone formation following gastric-bypass-induced rapid weight loss. Am J Surg 1995; 169: 91-96; discussion 96-97.
[37] Milone L, Strong V, Gagner M. Laparoscopic sleeve gastrectomy is superior to endoscopic intragastric balloon as a first stage procedure for super-obese patients (BMI> or = 50). Obes Surg 2005; 15 (5): 612-17.
[38] Han SM, Kim WW, Oh JH. Results of laparoscopic sleeve gastrectomy (LSG) at 1 year in morbidly obese Korean patients. Obes Surg 2005; 15 (10): 1469-75.
[39] Catheline JM, Cohen R, Khochtali I, *et al*. [Treatment of super super morbid obesity by sleeve gastrectomy]. Presse Med 2006; 35(3 Pt 1): 383-87.
[40] Langer FB, Bohdjalian A, Felberbauer FX, *et al*. Does gastric dilatation limit the success of sleeve gastrectomy as a sole operation for morbid obesity? Obes Surg 2006; 16 (2): 166-71.
[41] Cottam D, Qureshi FG, Mattar SG, *et al*. Laparoscopic sleeve gastrectomy as an initial weight-loss procedure for high-risk patients with morbid obesity. Surg Endosc 2006; 20 (6): 859-63.
[42] Himpens J, Dapri G, Cadière GB. A prospective randomized study between laparoscopic gastric banding and laparoscopic isolated sleeve gastrectomy: results after 1 and 3 years. Obes Surg 2006; 16: 1450-56.
[43] Roa PE, Kaidar-Person O, Pinto D, Cho M, Szomstein S, Rosenthal RJ. Laparoscopic sleeve gastrectomy as treatment for morbid obesity: technique and short-term outcome. Obes Surg 2006; 16 (10): 1323-26.
[44] Silecchia G, Boru C, Pecchia A, *et al*. Effectiveness of laparoscopic sleeve gastrectomy (first stage of biliopancreatic diversion with duodenal switch) on co-morbidities in super-obese high-risk patients. Obes Surg 2006; 16 (9): 1138-44.
[45] Hamoui N, Anthone GJ, Kaufman HS, Crookes PF. Sleeve gastrectomy in the high-risk patient. Obes Surg 2006; 16 (11): 1445-49.
[46] Lee CM, Cirangle PT, Jossart GH. Vertical sleeve gastrectomy for morbid obesity in 216 patients: report of two-year results. Surg Endosc 2007; 21(10): 1810-16.
[47] Weiner RA, Weiner S, Pomhoff I, Jacobi C, Makarewicz W, Weigand G. Laparoscopic sleeve gastrectomy-influence of sleeve size and resected gastric volume. Obes Surg 2007; 17: 1297-305.
[48] Braghetto I, Korn O, Valladares H, *et al*. Laparoscopic sleeve gastrectomy: surgical technique, indications and clinical results. Obes Surg 2007; 17: 1442-50.
[49] Dapri G, Vaz C, Cadière GB, Himpens J. A prospective randomized study comparing two different techniques for laparoscopic sleeve gastrectomy. Obes Surg 2007; 17 (11): 1435-41.
[50] Givon-Madhala O, Spector R, Wasserberg N, *et al*. Technical aspects of laparoscopic sleeve gastrectomy in 25 morbidly obese patients. Obes Surg 2007; 17: 722-27.
[51] Lalor PF, Tucker ON, Szomstein S, Rosenthal RJ. Complications after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis 2008; 4: 33-38.
[52] Parikh M, Gagner M. Laparoscopic hiatal hernia repair and repeat sleeve gastrectomy for gastroesophageal reflux disease after duodenal switch. Surg Obes Relat Dis 2008; 4: 73-75.
[53] Serra C, Baltasar A, Andreo L, *et al*. Treatment of gastric leaks with coated self-expanding stents after sleeve gastrectomy. Obes Surg 2007; 17 (7): 866-72.
[54] Eisendrath P, Cremer M, Himpens J, Cadière GB, Le Moine O, Devière J. Endotherapy including temporary stenting of fistulas of the upper gastrointestinal tract after laparoscopic bariatric surgery. Endoscopy 2007; 39 (7): 625-30.
[55] Baltasar A, Bou R, Bengochea M, Serra C, Cipagauta L. Use of a Roux limb to correct esophagogastric junction fistulas after sleeve gastrectomy. Obes Surg 2007; 17 (10): 1408-10.
[56] Gagner M, Rogula T. Laparoscopic reoperative sleeve gastrectomy for poor weight loss after biliopancreatic diversion with duodenal switch. Obes Surg 2003; 13 (4): 649-54.
[57] Baltasar A, Serra C, Pérez N, Bou R, Bengochea M. Re-sleeve gastrectomy. Obes Surg 2006; 16 (11): 1535-38.

Received: April 28, 2008 Revised: June 19, 2008 Accepted: July 7, 2008