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A Feasibility Study of Novel "Laparoscopic Sleeve Gastrectomy with Loop Gastroileal Bypass" for Obesity: An Indian Experience

Amar Vennapusa[1], Bhargav R. K. Panchangam[2], Mukharjee S. S. Madivada[3]

[1]*Department of Bariatric and Metabolic Surgery, Dr Amar Bariatric and Metabolic Center, Hyderabad, India*

[2]*Department of Endocrine and Metabolic Surgery, Endocare Hospital, Vijayawada, India*

[3]*Department of Cardiology, Pulse Heart Center, Hyderabad, India*

Objective: This study is aimed to evaluate the safety, feasibility, and efficacy of a novel technique: laparoscopic sleeve gastrectomy with loop gastroileal bypass.

Summary of Background Data: Standard bariatric surgeries, such as sleeve gastrectomy and Roux-en-Y gastric bypass, although very effective, carry certain inherent limitations and inevitable sequelae. Newer bariatric/metabolic surgeries are required to address these limitations.

Methods: Between February 2016 and February 2018, a total of 113 Indians suffering from obesity with or without type 2 diabetes underwent sleeve gastrectomy with loop gastroileal bypass. Meticulous analysis of prospectively documented data was performed.

Results: Mean age was 40.74 ± 10.4 years, mean body mass index was 43.48 ± 7.57 kg/m^2. A total of 54 of 113 patients (47.79%) had type 2 diabetes. Mean duration of surgery was 148.36 ± 38.56 minutes. Common channel length was 250 cm in 18 patients, 300 cm in 88 patients, and 350 cm in 7 patients. There were no major complications, such as major intra-abdominal bleeding, perforation, or leak. According to Indian standards, when 23 kg/m^2 was taken as a cutoff upper limit for normal weight, percentage of excess weight loss was 25.04% ± 10.13%, 67.81% ± 23.17% and 94.33% ± 24.96%, respectively, at 1, 6, and 12 months after surgery. A total of 51 of 54 patients with type 2 diabetes stopped using antidiabetes medications within 1 week after surgery.

Conclusion: Laparoscopic sleeve gastrectomy with loop gastroileal bypass appears to be a promising procedure to address limitations associated with standard bariatric procedures.

Corresponding author: Amar Vennapusa, FNB, MS, DNB, MRCSEd, Dr. Amar Bariatric & Metabolic Center, Workafella Business Centre, Plot No. 6-3-252/2, Sriram Nest, Mega City No 716, Erramanzil, Somajiguda, Hyderabad 500082, India.
Tel.: 00919676675646; E-mail: drvamar@gmail.com

Worldwide, the number of patients with excess weight is increasing at an alarming rate. Although healthy diet and exercise are necessary to prevent obesity, they have proved to be less effective in treating severe obesity.[1] As of now, bariatric/metabolic surgery is the only effective option available for long-lasting and effective weight loss. Sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB) are the most widely practiced bariatric surgeries.[2,3] In the recent past, mini–gastric bypass (MGB) became popular because of its effectiveness.[4] All of these surgeries, although effective, have certain inherent limitations and sequelae. Biliopancreatic diversion with duodenal switch (BPD DS) is the most effective bariatric surgery to date, but it is not widely practiced, probably because of its technical complexity and severe malabsorption.[5,6] To address the limitations of standard bariatric surgeries several newer bariatric/metabolic surgeries have been introduced, which include ileal interposition with sleeve gastrectomy,[7] loop duodenojejunal bypass with sleeve gastrectomy,[8] sleeve gastrectomy with duodenojejunal bypass,[9] and single-anastomosis duodenoileal bypass with sleeve (SADI S).[10] SADI S is a loop modification of BPD DS. Malabsorption is relatively less compared with BPD DS because of 200 to 250 cm of common channel, but it is still a concern in several patients. Increasing common channel length to 300 cm reduces malabsorption significantly.[11,12] But, access to the biliary tract is lost in the SADI S procedure. Sleeve gastrectomy with loop gastroileal bypass (SG LGIB; Fig. 1) is technically a modification of SADI S. It is very similar to sleeve gastrectomy with loop bipartition[13] or single-anastomosis sleeve ileal (SASI) bypass,[14] but with a few technical variations. SG LGIB is a simple operation in which sleeve gastrectomy is performed and ileum ≥300 cm proximal to ileocecal junction is anastomosed in a loop fashion to the pyloric antrum. In this context, we evaluated the efficacy and feasibility of this novel SG LGIB as an optimal metabolic surgical procedure.

Methods

This is a prospective study of SG LGIB in patients with obesity with or without type 2 diabetes (T2D). We ensured that the study complied with international ethics norms according to the Helsinki Declaration–Ethical Principles for Medical Research Involving Human Subjects.[15] All of the patients received a detailed explanation about the advantages and disadvantages of standard and novel bariatric surgeries, and those who were willing to undergo SG LGIB were included in this study. Between February 2016 and February 2018 we performed SG LGIB on 115 obese patients with obesity with or without T2D. A total of 113 patients who fulfilled inclusion criteria were assessed for the safety and feasibility of this surgery. Inclusion criteria were age 18 to 65 years, body mass index (BMI) ≥30 kg/m^2, no psychiatric problems, those who were willing to undergo follow-up, and those who completed minimum 1 month of follow-up. Exclusion criteria were severe cardiopulmonary disease, cirrhosis of liver, chronic smoking, and alcohol abuse. Routine preoperative workup was done and their fitness for surgery was assessed. Surgery was performed under general anesthesia. Via 3 ports, sleeve gastrectomy was performed, starting 6 cm proximal to pylorus. Gastroileal

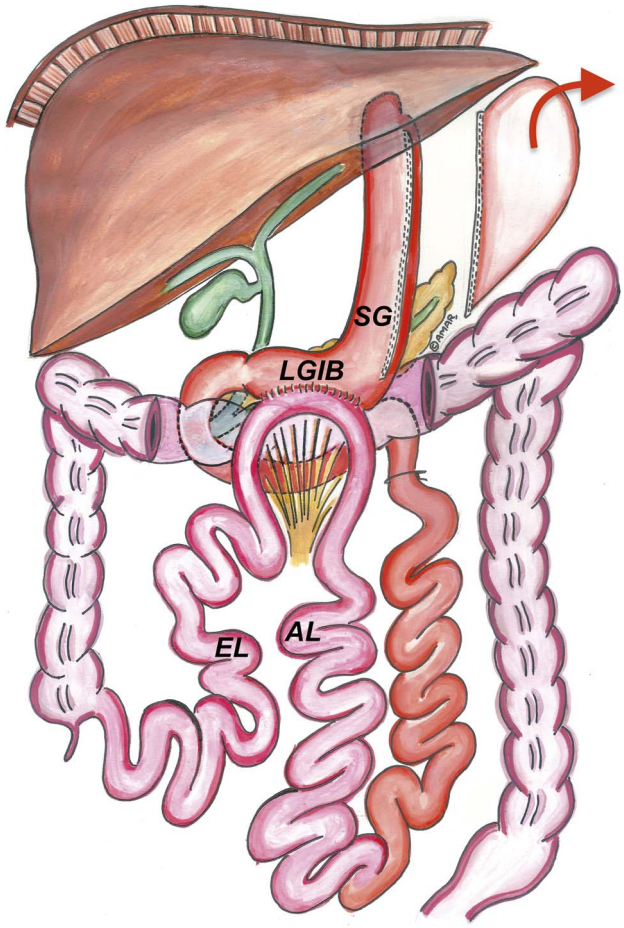

Fig. 1 Pictorial diagram of sleeve gastrectomy with loop gastroileal bypass: SG, LGIB, afferent limb (AL), and efferent limb (EL).

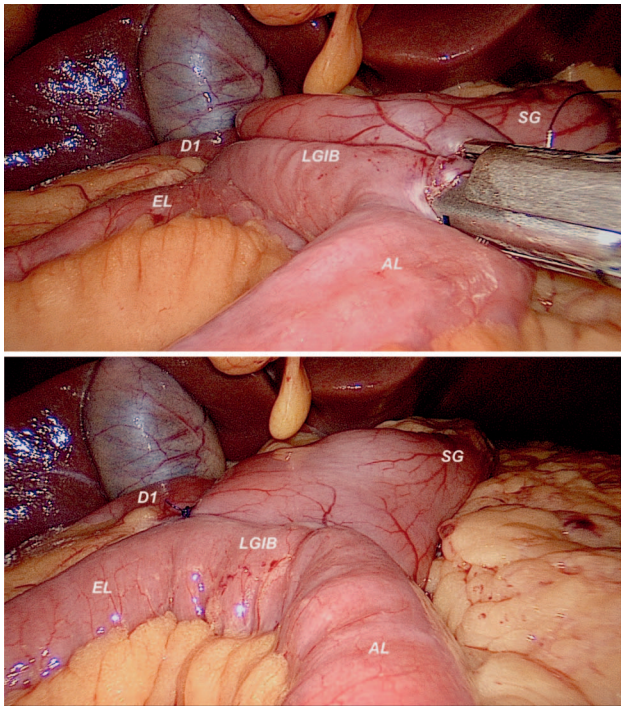

Fig. 2 Intraoperative photographs of horizontal stapled anastomosis: SG, LGIB, afferent limb (AL), efferent limb (EL), and first part of the duodenum (D1).

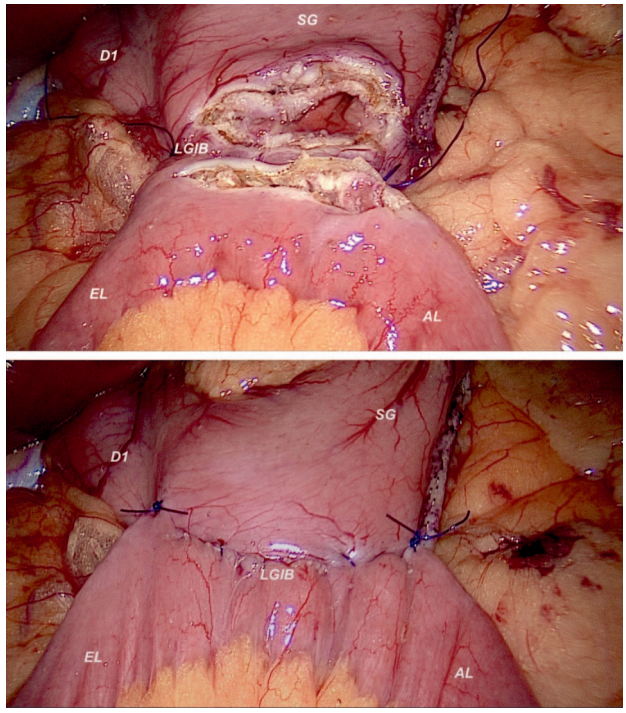

Fig. 3 Intraoperative photographs of horizontal sutured anastomosis: SG, LGIB, afferent limb (AL), efferent limb (EL), and first part of the duodenum (D1).

anastomosis of 4 cm in size was performed between pyloric antrum and antimesenteric border of ileum, 300 or 350 cm proximal to the ileocecal junction, either by a horizontal stapled or totally hand-sewn method in 2 layers (Figs. 2 and 3). All of the patients were discharged from the hospital within 72 hours.

For statistical evaluation, the entire cohort was divided into 3 groups based on follow-up duration: group A, 113 patients, at 1-month follow-up; group B, 104 patients, at 6-month follow-up; and group C, 56 patients, at 1-year follow-up. At follow-up, leak test was performed at 7 days and 1 month, using either ultrasound abdomen and diluted barium meal X-ray of stomach or computed tomography (CT) of abdomen with oral and intravenous contrast. Endoscopy was planned at 6 months after surgery, 1 year after surgery, and yearly thereafter. Diabetes was considered to be under partial remission when antidiabetes medications were reduced or discontinued but HbA1C was still $\geq$6% and/or fasting plasma glucose level was $\geq$100 mg/dL. Complete remission of diabetes was considered when HbA1C was $<$6% and fasting plasma glucose was $<$100 mg/dL without antidiabetes medications.

Statistical analysis

Numbers (Apple Inc, Cupertino, California) software was used for statistical analysis. Descriptive analysis was done for categoric variables. *P* value of $<$0.05 was considered as statistically significant.

Results

Of 113 patients, 66 were male and 47 were female. Mean age ($\pm$ SD) was 40.74 $\pm$ 10.4 years, mean weight was 117.38 $\pm$ 22.56 kg, and mean BMI was 43.48 $\pm$ 7.57 kg/m^2. A total of 54 of 113 patients (47.79%) had T2D, and 16 of 113 patients (14.16%) had prediabetes. All patients were on oral hypoglycemic agents. A total of 8 of them were on insulin. Mean duration of T2D was 3.49 years. Other comorbidities are depicted in Table 1.

Gastroileal anastomosis was done by vertical stapling in an initial 11 patients, horizontal stapling in 83 patients, and horizontal completely hand-sewn procedure in 19 patients. Size of the anastomosis was 4 cm in 107 patients and 3 cm in 6 patients. Common channel length was 250 cm in 18 patients, 300 cm in 88 patients, and 350 cm in 7 patients. Greater omentum was divided into 2 halves in all

Table 1 Frequency distribution of comorbidities

Comorbidity	No. (%)
Hypertension	51 (45.13)
Hyperlipidemia	30 (26.55)
Snoring	99 (87.61)
Obstructive sleep apnea	23 (20.35)
Knee joint pains	30 (26.55)
Osteoarthritis of knee joints	10 (8.85)
Hypothyroidism	31 (27.43)
Preoperative gastroesophageal reflux disease	3 (2.65)

patients, except the initial 10 patients in whom it was initially undivided, at the site of planned gastroileal anastomosis. Mean duration of surgery was 148.36 ± 38.56 minutes. Of 113 patients, 6 underwent adhesiolysis, 6 umbilical hernia repair, 5 cholecystectomy, and 1 ovarian cystectomy in addition to the SG LGIB surgery. Mean hospital stay was 2.86 ± 0.52 days. None of the patients had major complications, such as intra-abdominal bleeding, perforation, leak, or obstruction. There was no 30-day mortality. A total of 102 of 113 patients were evaluated with an ultrasound scan of abdomen, diluted barium meal X-ray at 1 week, and 108 of 113 were evaluated at 1 month after surgery to rule out leak and to assess differential flow of barium into proximal bowel and ileum. A total of 11 of 113 at 1 week, and 5 of 113 at 1 month, of follow-up were evaluated with CT abdomen with oral and intravenous contrast to assess the same. Radiologic findings suggested preferential flow of contrast into ileum.

Minor complications, such as hematemesis, midzone pneumonia, and fever, occurred in 2.65% of patients, which were either self-limiting and/or manageable conservatively. Gallbladder sludge was detected in 58 of 107 patients (54.21%) 1 week after surgery. A total of 35 of 99 patients (35.35%) and 17 of 52 patients (32.69%) had cholelithiasis at 6 months and 1 year of follow-up, respectively. Two patients required cholecystectomy.

Mean weight, weight loss, BMI, and BMI reduction in all groups are summarized in Table 2. We calculated efficacy parameters, such as excess weight, excess BMI, and percentage of excess weight loss (percentage of excess BMI reduction) as per Indian standard cutoff for obesity (*i.e.*, 23 kg/m^2) and global standard cutoff (25 kg/m^2) in all 3 groups. Comparison of efficacy parameters between the 3 groups against both standard cutoffs is shown in Table 3.

At time of follow-up, the BMI of 12 of 104 patients (11.54%) was less than 23 kg/m^2, and 18 of 104 patients (17.31%) was less than 25 kg/m^2 in group B. Similarly, the BMI 20 of 56 patients (35.71%) was less than 23 kg/m^2, and 32 of 56 patients (57.14%) was less than 25 kg/m^2 in group C. Two of the group C patients were underweight, with BMI falling below 18.5.

Mean preoperative HbA1C and fasting plasma glucose in 54 diabetic patients were 7.59% ± 1.15% and 176.2 ± 43.67 g/dL, respectively. Among these, 50 completed 6-month and 25 patients completed 1-year follow-up. The diabetic parameters are summarized in Table 4.

A total of 51 of 54 patients with diabetes stopped using antidiabetes medications within 1 week after surgery. All of these individuals with diabetes were off the medications at 6 and 12 months of follow-up. HbA1C was <6% and fasting plasma glucose was <100 mg/dL in 39 of 50 patients with diabetes (78%) at 6 months of follow-up and 24 of 25 patients (96%) at 12 months of follow-up. At 6 months of follow-up 41 of 45 individuals, and at 12 months of follow-up 17 of 18 individuals, with hypertension were normotensive without medications.

In group B, 3 of 18 patients (16.67%) and 5 of 86 patients (5.81%), and in group C 2 of 17 patients (11.76%) and 1 of 39 patients (2.56%) with 250 and 300 cm of common channel, respectively, had serum albumin levels <3 g/dL. There was 1 patient who required reversal of loop gastroileal bypass because of persistent hypoalbuminemia and severe malnutrition at 10 months of follow-up. Remaining hypoalbuminemic patients improved with intravenous 20% albumin injections, followed later by diet counseling and a high-protein diet.

A total of 4 patients (3.54%) developed diarrhea after surgery. None of the patients had steatorrhea or fecal incontinence. A total of 52 of 113 patients (46.02%) complained of constipation after surgery. None of the patients had symptoms suggestive of dumping syndrome. A total of 97 of 104 group B patients underwent endoscopy. Bile froth was present in 85 of these 97 patients (87.63%), asymptomatic antral gastritis in 18 of 97 (18.56%) and bile pooling in 14 of 97 (14.43%). A total of 42 of 56 group C patients underwent endoscopy. Bile froth was present in 39 of 42 patients (92.86%), asymptomatic antral gastritis in 6 of 42 (14.29%), and bile pooling in 5 of 42 (11.91%). Patients with asymptomatic antral gastritis were prescribed sucralfate syrup thrice daily for 6 months. There was improvement in symptoms and endoscopic findings in 2 group B

Table 2 Intergroup comparison of weight loss (WL) efficacy

Parameter	Group A (113 patients, 1 mo)	Group B (104 patients, 6 mo)	Group C (56 patients, 12 mo)
Preoperative weight, kg	117.38 ± 22.56	117.7 ± 23.07	116.74 ± 23.91
Postoperative weight, kg	105.03 ± 21.02	83.47 ± 17.21	68.85 ± 11.81
WL, kg	12.35 ± 3.25	34.23 ± 9.59	47.90 ± 16.12
Preoperative BMI, kg/m^2	43.48 ± 7.57	43.32 ± 7.63	42.77 ± 7.31
Postoperative BMI, kg/m^2	38.93 ± 7.25	30.73 ± 5.81	25.39 ± 4.6
BMI reduction, kg/m^2	4.55 ± 1.07	12.59 ± 3.37	17.39 ± 4.87

patients and 1 group C patient with preoperative gastroesophageal reflux disease. None of the remaining group B and C patients who underwent endoscopy had reflux esophagitis or marginal ulcers. On endoscopy, 1 of 6 group C patients with 3-cm anastomosis was found to have anastomosis narrowed to 1 cm.

Discussion

Bariatric surgery is the most effective treatment option available for the treatment of obesity. Weight loss after bariatric surgery was initially thought to be mainly due to food restriction and malabsorption. But growing evidence suggests that weight loss and resolution of T2D are related to several hormonal changes, such as reduced ghrelin, anti-incretins, and gastric inhibitory peptide, and increased ileal hormones, such as GLP 1 and Peptide YY. The role of restriction and malabsorption appears to be secondary.[16]

SG and RYGB are the standard and most popular bariatric surgeries in the world today. Recently, MGB gained lot of attention and popularity because of its effectiveness and the ease of performing surgery. Standard bariatric surgeries have certain limitations. In SG, stapling starts 2 to 6 cm proximal to the pylorus, with bougie size varying between 32 and 36 Fr.[17] In SG, there is no diversion of undigested food. SG is simple and effective, but long-term weight regain risk is as high as 75.6%.[18] This weight regain is perhaps related to hormonal adaptation rather than loss of restriction. In RYGB, a small gastric pouch is created and is anastomosed to jejunum in a Roux-en-Y fashion. Alimentary limb length varies between 75 and 150 cm, and biliopancreatic limb length varies between 50 and 100 cm.[19] RYGB has problems, such as inability to monitor remnant stomach by upper GI endoscopy (at-risk gastric remnant), lack of access to biliary tract, complete exclusion of duodenum, and proximal jejunum leading to calcium and iron deficiencies, exclusion of pylorus leading to dumping syndrome, and increased risk of internal hernias due to mesenteric division.[20,21] All of these except internal hernias are problems even with MGB.[22] In BPD DS, after performing gastric sleeve, the first part of the duodenum is divided and anastomosed to the ileum in Roux-en-Y fashion, with an alimentary limb of 150 cm and common channel of 100 cm.[5] There is complete diversion of undigested food into the 250 cm of ileum, and mixing of food with biliopancreatic juices occurs only in the last 100 cm of ileum. BPD DS is the most effective bariatric surgery in terms of weight loss and resolution of T2D, but severe malabsorption is a serious concern. SADI S is a loop modification of BPD DS. In SADI S, after performing sleeve gastrectomy, the first part of the duodenum is divided and anastomosed to ileum in a loop fashion 200 to 250 cm proximally to

Table 3 Intergroup comparison of efficacy between standard cutoffs

Parameter	Group A (113 patients)	Group B (104 patients)	Group C (56 patients)
EW, kg			
23 BMI cutoff	55.01 ± 20.34	54.99 ± 20.86	53.89 ± 20.92
25 BMI cutoff	49.59 ± 20.27	49.53 ± 20.78	48.43 ± 20.77
EBMI, kg/m^2			
23 BMI cutoff	20.48 ± 7.57	20.32 ± 7.63	19.77 ± 7.31
25 BMI cutoff	18.48 ± 7.57	18.32 ± 7.63	17.77 ± 7.31
EWL%, EBMI reduction %			
23 BMI cutoff	25.04 ± 10.13	67.81 ± 23.17	94.33 ± 24.96
25 BMI cutoff	28.94 ± 13.94	78.20 ± 32.49	108.84 ± 36.6

EBMI, excess BMI; EW, excess weight; EWL, excess weight loss %.

Table 4 Intergroup comparison of diabetic parameters

Parameter	Preoperative (54 patients)	6 mo (50 patients)	12 mo (25 patients)
HbA1C, %	7.59 ± 1.15	5.34 ± 0.42	4.88 ± 0.42
FBS, mg/dL	176.2 ± 43.67	90.57 ± 12.71	79.32 ± 9.51

FPG, fasting plasma glucose.

the ileocecal junction.[10] In SADI S, undigested food enters into the distal 200 to 250 cm of ileum and mixes with biliopancreatic juices immediately after entering the ileum, becauase there is no separate alimentary limb. Although malabsorption is less compared with BPD DS, it is still a concern with this surgery when the common channel is 200 to 250 cm. Increasing the common channel to 300 cm reduces risk of malabsorption.[11,12] Like any other diversion, access to the biliary tract is lost in BPD DS and SADI S. In these surgeries, there is a risk of hypoglycemia, because of the unopposed action of incretin hormones.

In BPD DS and SADI S, direct entry of undigested food into the ileum is 100%, resulting in maximum distal gut hormonal changes, and so the effects of these surgeries on weight loss and diabetes resolution are significantly high, and chances of weight regain are low compared with SG or RYGB alone. There is diversion of bile and pancreatic juices, alteration in gut microbiota, and complex neurohormonal changes, which contribute to the effect of these surgeries. Complete diversion also results in the sufficient foregut hormonal changes needed for weight loss and T2D resolution. But complete diversion of food from most of the small intestine increases the risk of severe malabsorption. In contrast to BPD DS and SADI S, in SG there is no diversion, and there is minimal malabsorption but inadequate hormonal changes (to prevent weight regain and recurrence of T2D).

This leaves a middle-ground approach to the partial diversion of food. Santoro *et al*[23] modified BPD DS into sleeve gastrectomy with transit bipartition (SG TB), where after sleeve gastrectomy duodenum is not transected, but ileum is divided and directly anastomosed to the pyloric antrum in a Roux-en-Y fashion. In this surgery, the sleeve has 2 outlets. One is into the ileum through gastroileal bypass, and another is into the first part of the duodenum across the pylorus. SG TB surgery was performed in 1020 patients, with excellent outcomes.[23]

In SG LGIB, sleeve gastrectomy was performed starting 6 cm proximal to the pylorus, and ileum was anastomosed to pyloric antrum in a loop fashion 300 to 350 cm proximal to the ileocecal junction. So, the sleeve has 2 outlets—1 into the duodenum and jejunum across the pylorus, and another into the ileum across loop gastroileal anastomosis. Undigested food goes through both outlets. So basically, it is gastric sleeve with partial diversion. SG LGIB is a loop modification of SG TB. Loop modification probably reduces the risk of internal hernias because mesentery is not divided, and anastomotic ulcer risk is reduced because gastric juice is neutralized by biliopancreatic juice. SG LGIB is technically similar to SADI S, but without duodenal transection and with loop bypass to the pyloric antrum. These technical alterations have significant physiologic impact, with less malabsorption. SG LGIB is nothing but a sleeve gastrectomy with a loop anastomosis between pyloric antrum and ileum. It is very similar to SASI bypass and sleeve gastrectomy with loop bipartition, but with minor technical variations.

Mui *et al*[13] published results in 1 patient and named the surgery "sleeve gastrectomy with loop bipartition." Mahdy *et al*[14] published results in 50 patients and named the surgery "single anastomosis sleeve ileal (SASI) bypass." In SG LGIB and SG TB, there is partial diversion of food (approximately two thirds) into ileum, resulting in the sufficient hormonal changes necessary to maintain long-term weight loss, and long-term remission or resolution of T2D. Because food goes partially (approximately one third) into the duodenum and proximal jejunum as well, malabsorption risk is minimized. Levels of proximal gut hormones are maintained, leading to reduced risk of dumping syndrome. SG LGIB and SG TB can be considered as sleeve with partial bypass surgerues, which brings an optimal balance between physiologic changes and malabsorption.

It is evident that if food reaches the ileum directly, then distal gut hormonal changes will be maximal. But the complete diversion of food into ileum also causes malabsorption. It is not clear how much diversion is required to produce sufficient hormonal changes without causing malabsorption.

The anatomic and functional size of anastomosis, resistance across pylorus, and gastroileal bypass at any given point in time, type of food, quantity of food consumed, and posture at the time of food consumption play an important role in deciding the preferential flow of food and liquids in 2 routes. If anastomosis is small, more food uses the natural duodenojejunal pathway, leading to the reduced efficacy of surgery. Small anastomosis also increases the risk of anastomotic narrowing, leading to a reduced long-term effect of surgery. If anastomosis is big, more food uses the anastomotic route, leading to increased physiologic changes, but malabsorption also increases. The optimal size of anastomosis is 3 to 4 cm to balance between physiological changes and malabsorption.[23] Four centimeters was used in most of our patients, in order to allow the

preferential flow of food across gastroileal bypass. We consider 4 cm to be the ideal size of anastomosis to balance between hormonal changes and malabsorption.

Mahdy *et al*[14] used horizontal stapled loop gastroileal bypass of not more than 3 cm, between pyloric antrum 3 cm proximal to the pylorus and ileum at the 250-cm mark. Mui *et al*[13] used horizontal hand-sewn anastomosis to the ileum at the 250-cm mark. Our SG LGIB surgery has minor technical differences from sleeve gastrectomy with loop bipartition and SASI bypass. In our technique, common channel length was 300 or 350 cm, type of anastomosis was horizontal stapled or hand-sewn, and size of anastomosis was 4 cm. Location of loop gastroileal bypass was between the antimesenteric border of the ileum at the 300- or 350-cm mark and the anteroinferior aspect of pyloric antrum 1 cm above its greater curvature, 1 cm proximal to pylorus, and 1 cm distal to the staple line of the gastric sleeve. In our technique, the greater omentum was divided at the site of planned gastroileal anastomosis in order to reduce tension on anastomosis.

In our initial 11 patients we used vertical stapled anastomosis. When vertical stapled anastomosis was performed, we preferred anastomosis to the posterior wall of pyloric antrum, because the width of the vertical strip of pyloric antrum between the anastomotic staple line and the first staple line of the sleeve can be adjusted under vision before firing the anastomotic stapler. In this way we can keep sufficient width of the gastric antral strip between 2 staple lines, and blood supply to that area can be maintained. This is not a problem when horizontal anastomosis is used.

In SG LGIB, pyloric antrum is not freely mobile. Ileum has to be brought near the pyloric antrum. When we used vertical stapled posterior gastroileal bypass, tension on the upper part of the anastomosis appeared to be high even after applying anchoring sutures above anastomosis. Compared with vertical anastomosis, tension on the horizontal anastomosis is low. Vertical stapled anastomosis was discontinued in favor of horizontal anastomosis, and omental division at the site of planned anastomosis was added in order to further reduce tension on the anastomosis. Horizontal stapled anastomosis is relatively faster compared with horizontal hand-sewn anastomosis. So, we recommend horizontal stapled anastomosis for gastroileal bypass. Gap behind the anastomosis is less, but this is sufficient to prevent obstruction or strangulation in case any bowel loop enters into the gap. We did not close this gap in any of our patients.

As in SG TB, the sleeve has 2 outlets in SG LGIB. Because gastroileal bypass is wide and in a more dependent area, solids and liquids preferentially use this route. In our patients the preferential use of gastroileal bypass was observed in CT abdomen imaging with oral and intravenous contrast and barium meal X-ray of stomach. The same was shown by contrast studies in different published articles.[13,14,23] The advantages of adding gastroileal bypass to the sleeve is that most of the undigested food enters the ileum, leading to maximal stimulation of the distal gut, which in turn results in sufficient hormonal changes, such as increased GLP 1 and peptide YY, leading to more effective and long-standing weight loss as well as resolution of T2D.[23] Malabsorption risk is reduced because a portion of food still goes through the natural duodenojejunal route, as demonstrated by radiologic studies in our patients. The passage of a portion of food into the proximal bowel ensures keeping vitamin deficiencies, mineral deficiencies, and malabsorption to a minimum. SG LGIB is physiologically superior to sleeve gastrectomy alone because the physiologic changes required for weight loss and T2D resolution are greater. Perhaps increased physiological changes reduce the risk of weight regain in the future.

Because the sleeve has 2 outlets and one of them is wide and directly opens into the small bowel without any intervening value, the sleeve becomes a low-pressure zone. This can play an important role in reducing the risk of leak. None of our patients developed leak either at sleeve or anastomosis. Even though there is no valve at the gastroileal bypass, gastric musculature around the anastomosis acts as a functional valve. This phenomenon was observed on routine follow-up endoscopies. Low-pressure sleeve probably acts as an immunity against the development of reflux esophagitis, which can be a problem after sleeve gastrectomy. None of the patients had symptoms of reflux esophagitis, and endoscopy did not show any signs of new-onset gastroesophageal reflux disease.

One concern with loop gastroileal bypass is the entry of bile or ileal contents into the stomach. On endoscopy, bile was found to come into the stomach across both pylorus and gastroileal bypass, although mainly across the latter. Whatever enters into sleeve will rapidly leave across both outlets, although preferentially across the gastroileal bypass. The same is true for the bile entering into the sleeve.

Bile leaves across both outlets, preferentially across the wide and more dependent gastroileal bypass. Long-term consequences of the transient presence of bile in the sleeve are not clear. Ileal bile is relatively weaker, so it should be less irritating to gastric mucosa. This is evidenced by the fact that none of our patients had symptoms of gastritis, even though endoscopy showed antral gastritis in some patients. The presence of bile in the sleeve can be explained by the Venturi effect.[24] Marginal ulcer risk should be lower becaus gastric acid is neutralized by biliopancreatic juices across anastomosis. Marginal ulcers were not present in any of our patients who had endoscopy. Risk of marginal ulcers in the Mahdy *et al*[14] series was 3.3%.

In SG, because there is no diversion, malabsorption is minimal.[25] In RYGB, because duodenum and proximal jejunum are bypassed, malabsorption of protein, vitamins, and minerals is possible.[20] Because there is a long common channel, protein malabsorption is relatively less compared with BPD DS. Presence of pylorus, the first part of the duodenum in BPD DS, and SADI S should limit the risk of protein, vitamin, and mineral malabsorption, but malabsorption risk is still high, because most of the small intestine is completely bypassed. In BPD DS, protein malabsorption risk is very high.[26] But in SADI S, the presence of 200 to 250 cm of common channel reduces the risk of malabsorption, compared with BPD DS.[10] Thus, malabsorption is directly proportional to the length of intestine bypassed and inversely proportional to the length of common channel. In SG LGIB, there is only partial diversion. Because undigested food also enters the duodenum and jejunum across the pylorus, malabsorption risk is relatively lower compared with RYGB, SADI S, and BPD DS, but risk is greater compared with SG.[13,14] In summary, the malabsorption risk appears to be in the following order: BPD DS > SADI S > RYGB > SG LGIB > SG. Analyzing the malabsorption of individual vitamins and minerals is beyond the scope of this article.

Compared with RYGB and MGB, the definite advantages of SG LGIB surgery are that there is no at-risk gastric remnant, access to biliary tract is maintained, and risk of calcium and iron deficiencies is lower. In any surgery where there is a complete diversion of food away from the proximal bowel and directly into the distal bowel, there is a risk of hypoglycemia because a rise in hindgut hormones goes unchecked by the foregut hormones. Entry of nutrients into proximal bowel ensures that anti-incretin levels and gastric inhibitory peptide levels are maintained, which keeps incretin hormones in check and reduces the risk of hypoglycemia. Whether this hinders the resolution of T2D in patients who have uncontrolled T2D has to be studied. Dumping syndrome is theoretically possible because there is no valve controlling nutrient output into the ileum through gastroileal bypass. But it is very rare because levels of anti-incretins are maintained that prevent hypoglycemia. None of our patients had symptoms of dumping.

SG LGIB has few advantages compared with SG TB. In SG LGIB, common channel length is greater, further reducing the risk of malabsorption; risk of internal hernias in between the layers of divided small bowel mesentery is avoided; risk of anastomotic ulcers is reduced, because biliopancreatic juice neutralizes gastric acid at the site of anastomosis; and there is single anastomosis instead of two anastomoses. SG LGIB has a place somewhere between SG and SADI S. One advantage of SG LGIB is that it can be converted to either SG or modified SADI S easily. One staple firing across gastroileal anastomosis converts SG LGIB to SG, and one staple firing across the first part of the duodenum converts SG LGIB into a modified SADI S.

Another obvious advantage is the preservation of natural endoscopic access to the biliary tract, and if there is any issue of choledocholithiasis in the future, that can be dealt with by endoscopy. One of the patients who developed gallbladder stones postoperatively also had obstructive jaundice due to choledocholithiasis, which was successfully dealt with by ERCP. SG LGIB is technically a modification of SADI S, which in turn is a loop modification of BPD DS. The main purpose of this modification is to maintain efficacy but reduce malabsorption. To the best of our knowledge, this is the largest series of SG LGIB technique in the published world literature.

Conclusions

Research in novel bariatric/metabolic surgical procedures is needed to address the limitations of standard bariatric procedures, such as SG and RYGB. In this direction, SG LGIB appears to be a more physiologic and efficacious novel bariatric/metabolic procedure in terms of better weight loss, diabetes resolution, and safety, and less malabsorption and nutritional deficiency. The logical and evident advantages of SG LGIB as shown in our study need to be replicated from varied geographic

zones to catapult it into a standard and optimal bariatric/metabolic procedure.

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