Revisional Surgery: Sleeve to Single Anastomosis Sleeve Ileal (SASI) Bypass

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1 Introduction

Obesity and diabetes comprise a great health epidemic, involving millions of people. Morbid obesity, however, is a problem that cannot be prevented by a healthy diet and exercise alone [1]. Recently, Second Diabetes Surgery Summit (DSS-II), had recommended inclusion of bariatric/metabolic surgery among glucose-lowering interventions for select patients with type 2 diabetes mellitus (T2DM) and obesity [2]. The mechanism in which this weight loss and control of metabolic syndrome is attained involves a detailed understanding of the way the gut anatomy is modified, interconnected with the role of gut hormones and microbiota [3, 4]. Metabolic surgery represents the new hope to control both diseases in one shot. The concept of metabolic surgery involves operations and procedures to treat metabolic diseases, such as T2DM [5]. These procedures encompass operating on normal organs to procreate effects beneficial to treat medical health problems. Bariatric surgery now represents a developed form of metabolic surgery that is used on a large scale to fight obesity and metabolic syndrome through more than 50 implemented surgical operations [6–8]. However, recently it has been reported that up to 10–50% of inadequate weight loss or weight regain patients who underwent an initial restrictive bariatric procedure will require another secondary bariatric surgical rescue operation [9].

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2 Rationale for Another Bariatric Surgical Procedure Following Sleeve Gastrectomy

Sleeve gastrectomy (SG) is mainly a restrictive procedure that has become one of the most commonly performed stand-alone bariatric operations due to its efficacy in achieving weight loss and attractive improvement of comorbidities, easiness to perform, better quality of life, and absence of complications of other complex procedures like marginal ulceration, internal herniation, malabsorption and dumping syndrome [10]. However, with the higher number of SGs performed and availability of long term results, a higher appearance of post SG consequences will become present that raise alarm, like sleeve stenosis, intractable severe reflux, or suboptimal results such as weight loss failure (inadequate weight loss and weight regain especially in super obese) and inadequate remission or relapse of T2DM [11]. This leads predominately to revision of the gastric sleeve or a conversion to a diversion procedure such as Roux-en-Y Gastric Bypass (RYGB), Mini Gastric Bypass (MGB), Single-anastomosis Duodeno-Ileal Bypass with Sleeve (SADI-S), or Duodenal switch (DS). Some identified causes of weight regain following SG in patients at least 2 years post-surgery include: a large retained fundus, increased ghrelin levels, inadequate follow-up support, and maladaptive lifestyle behaviors [12].

3 Options of Secondary Bariatric Procedures Following Suboptimal Sleeve Gastrectomy Results: What is the Rightful Choice?

Although revisional bariatric surgery is usually complex, technically demanding and riskier in terms of postoperative complications than that of primary procedures, with a perioperative morbidity rate of 19–50% [13]; it can be done safely by well-trained experienced bariatric surgeons in special bariatric centers [14]. Revisional surgery rates following SG are variable worldwide; it accounts for about 1.1% of bariatric procedures over a 6 year follow-up as proven in a Swedish study, 1.7% over 6 years in a high volume center in the US, up to 4.2% in Norway over 5 years, 6.4% in a study from Turkey over 7 years, and 6.6% over 7 years in a Canada center [9, 10, 15–17]. Re-sleeve gastrectomy is suitable only for patients with large gastric pouch after the original sleeve. However, it has higher risk of complications such as gastric fistula formation compared to the primary sleeve procedure that may be difficult to manage, and is also of lower efficacy in comparison to other revisional procedures like DS [18, 19]. Reversal of SG to RYGB also carries problems, such as inability to monitor gastric residue by upper gastro-intestinal endoscopy keeping it under risk, lack of access to biliary tract, complete exclusion of the duodenum and proximal jejunum leading to calcium and iron deficiencies, complete bypassing of the pylorus leading to dumping syndrome, and increased risk of internal hernias due to mesenteric division [20, 21]. MGB has recently come into light, becoming a familiar competitive procedure in the last decade because of its effectiveness, however, has approximately the same limitations, in addition to alkaline reflux gastritis [22, 23].

Research recently shed light on the correlation between gastrointestinal physiology and the metabolic pathways in response to operative and anatomical changes of the classic restriction and/or malabsorption mechanisms [24]. Biliopancreatic diversion with duodenal switch (BPD-DS) effects can be explained by neurohormonal modulation and alterations of the microbiota and bile salt metabolism resulting from initial and strong distal intestinal stimulation, making malabsorption an unnecessary and avoidable side effect [25]. This understanding helped form the current surgical set up as well as create future possibilities for metabolic surgery [26].

Although classic malabsorptive operations such as the BPD-DS are the most effective surgery's known given that they promote the best weight loss [90% excess weight loss (EWL)], and glycemic control than other techniques [27], its greater technical complexity, gastrointestinal complications and long-term nutritional risks that requires long-life follow up have limited its use [28].

SADI-S is a loop modification of the BPD-DS [29]. Malabsorption is relatively lower compared to BPD-DS because the common channel length is between 200 to 250 cm, and has even been recently increased to 300 cm to lessen hypoalbuminemia and dramatic malabsorption effects, but it is still considered a procedure causing concern in several patients [30, 31]. Furthermore, access to the biliary tract is lost in the SADI-S procedure. These procedures that are dominantly diversion related may result in atrophy of the mucosa. This is proven histologically by the flattening of intestinal villi and an increase in mitotic frequency, which may be followed by bacterial translocation and hepatic decompensation of already altered hepatic function by nonalcoholic fatty liver disease in obese patients [32, 33]. Additionally, proximal intestinal exclusion will initiate increased secretion and unopposed incretin action that eventually leads to the risk of hypoglycemia. That, plus the continuing weight loss adds to the malabsorptive effect [34].

4 The Rising Concept of Bipartition in Bariatric Surgery

Santoro et al. [35] introduced new operative modifications to the BPD-DS in the year 2003 making it safer and easier to perform, with comparable dramatic weight loss and comorbidity resolution, while reducing its adverse effects. The procedure entails sleeve gastrectomy with transient intestinal bipartition (SG-TB), in which a gastro-ileal anastomosis in a Roux-en-Y fashion is done to the pre-pyloric region, at a point 250 cm from the ileocecal junction reconstruction. This technique differs from the classic BPD-DS given that there is no exclusion of intestinal segments. The purpose of this new surgical technique is to promote only a partial exclusion of the proximal bowel and to boost early distal intestinal stimulation [36]. In addition, the preservation of some duodenal food flow has many advantages like nutritional protection, ensuring full access to the digestive tract, maintaining proximal protective mechanisms against hypoglycemia and micronutrient absorption capacity [36, 37].

5 Single Anastomosis Sleeve Ileal (SASI) Bypass: Pathophysiological Merits and Role in Weight Reduction and T2DM Remission

SASI bypass was born as a loop modification of the SG-TB of Santoro rather than the Roux-en-Y double anastomosis (Fig. 1) [36]. It Gained its name and popularity by Mahdy et al. [33], and since, has erupted as a unique bariatric and metabolic model representing a bipartition technique to treat obesity, diabesity or weight regain after SG. It acts by decreasing ghrelin secretion through sleeve gastrectomy while increasing the flow of food majorly through the gastro-ileostomy instead of the pylorus, which is thought to intensify hindgut stimulation rather than the foregut that provides positive intervention with the neuroendocrine control of hunger and satiety and not causing harm to the important digestive processes unrelated to obesity. It only has one intestinal anastomosis which in turn is associated with less anastomotic complications and shorter operative time [33]. The perception of nutrients in the distal bowel makes SASI patients eat less food due to a hypothalamic-generated satiety sensation [39]. The profound distal bowel stimulation reduces proximal gastrointestinal activity through the distal gut hormones such as glucagon like peptide-1 (GLP-1), which has central satietogenic effects, and reduces gastric emptying by the ileal break mechanism [40–42].

Like the SG-TB, the SASI is described as safer and easier to perform than BPD-DS and carries similar weight-loss benefits without the nutrient deficiencies and protein caloric malnutrition seen with the latter. The duodenum and papilla

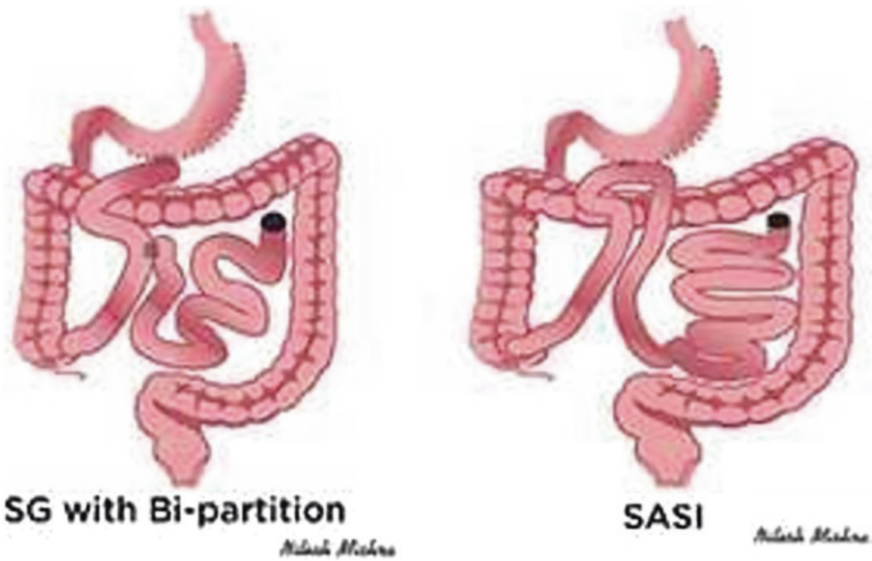

Fig. 1 Original Santoro et al. SG-TB procedure and SASI Bypass [38]

continue to be endoscopically accessible, with satisfactory short-term follow-up evidence now available for the SASI bypass [4].

6 SASI Bypass Technique

The operation is done as a two step procedure; SG followed by gastro-ileostomy, or a single complementary step added to the previously performed SG under general anesthesia. The latter is performed in the following steps:

The operating table is set in a horizontal position and the surgeon positioned on the left side of the patient. The procedure starts using 12-mm optical trocar to enter the abdomen under direct vision about 20 cm below the xiphoid process and 3 cm to the left side of the midline. Pneumo-peritoneum is achieved with carbon dioxide at 15 mmHg. Four additional ports are placed under direct vision, using the same sites as in SG. The ileocecal junction is identified and 250 cm is measured upwards. The selected loop is ascended without division of the greater omentum, and is stapled iso- peristaltic side-to-side to the anterior wall of the antrum of the stomach, just 3 cm away from the pylorus with a linear stapler charged with a green cartridge, the diameter of ileal antrum anastomosis should not exceed 3 cm in diameter. The anterior wall of the anastomosis is closed with a two-layer running 3/0 polydioxanone suture [33].

7 SASI Bypass Clinical Outcomes for Weight Regain and T2DM Remission

Mahdy et al.'s report was one of the initial studies that demonstrated the efficacy of the SASI bypass technique and included 50 patients [mean body mass index (BMI) 48.7 ± 7.6 kg/m^2]. The patients experienced significant (90%) excess weight loss (EWL) at 1 year. Also, serum glucose level was normalized in 100% of patients at 3 months, and all patients discontinued insulin and oral hypoglycemic medications [33]. In another study, Salama et al. reported on a 1-year follow-up of 45 patients (mean BMI 43.2 kg/m^2) BMI had decreased to 29.1 kg/m^2. Fasting plasma glucose (FPG), low-density lipoprotein (LDL), and insulin use were statistically significantly decreased, while high-density lipoprotein (HDL) was significantly increased [43]. In a multicenter study done also by Mahdy et al., fifty-eight patients underwent the SASI bypass after unsatisfactory SG outcomes. A significant decrease in weight and BMI from the mean preoperative weight at 12 months after SASI was recorded. The mean % total weight loss (TWL) at 12 months postoperatively was 17.3 ± 9.3 and the mean % EWL was 40.9 ± 22.1. Complete remission of T2DM was also documented, with complete remission of hypertension in 16.6%, while none of the patients with dyslipidemia or obstructive sleep apnea syndrome (OSAS) showed remission of their comorbidities [4].

The remarkable impact of the SASI bypass on glycemic control in diabetic patients is a major advantage of this procedure, with remission rates reaching

100%. This finding would suggest that the SASI bypassis an excellent option for patients with obesity and T2DM. As the procedure entails only a single gastroileal anastomosis, the risk of anastomotic complications may theoretically be less than other procedures that include more than one anastomosis [4]. In terms of comparison with SG-TB it is found to be more effective and simpler to perform, while also being an easily reversible technique.

Lower preoperative BMI and lower body weight were reported to predict higher %EWL after the SASI bypass. It should be emphasized that higher preoperative BMIs (>50 kg/m^2) scored poorer outcomes and lower % EWL after SG [44]. Performing the SASI to overcome sub-standard outcomes after SG was also associated with significantly lower % EWL (40.9 vs. 63.9%) compared with performing the SASI bypass as a primary bariatric procedure. Although weight regain was not observed in patients who underwent the SASI bypass compared with more than 5% of patients who underwent SG [12].

Furthermore, the SASI bypass was associated with significant improvement in other obesity-associated comorbidities, particularly gastroesophageal reflux disease (GERD) which is a considerable issue for the predominantly restrictive bariatric procedures such as SG. Moreover, research has proven that the leakage and GERD rates from SG was significantly decreased after performing gastrojejunostomy due to a decrease in the stomach tube pressure [45]. It is also worth mentioning that recent reports disclosed possible Barrett's esophagus risk following SG due to exposure of the distal esophagus to severe reflux, with de novo reflux seen in up to 23% of patients [46–48].

8 SASI Bypass Perioperative Morbidity, Reversal/Revision

Salama et al. reported no mortalities in their study, with minimal postoperative nutritional complications in comparison to other procedures, reduced dumping syndrome and diarrhea [43]. Complications in the Mahdy et al. initial study included one complete obstruction at the gastroileal anastomosis, one post-operative internal hemorrhage, one pulmonary embolism, seven bilious vomiting and one leak in the biliary limb. At 6 months, one patient was diagnosed with a marginal ulcer; at 1 year, one patient was re-operated on to hault potential excessive weight loss, but no mortalities were seen [33]. From the multicenter study which included more than 600 patients, Mahdy et al. reported fifty-six (10.1%) complications after the SASI bypass, which is slightly higher than the mean overall complication rate after SG (8.7%) [4, 30]. Four (0.72%) patients required readmission within 30 days after surgery. However, the vast majority of morbidities after SASI bypass were minor, graded as grade I or II on the Clavien-Dindo scale. Complications included bilious vomiting, diarrhea, stomal ulcer, calcular obstructive jaundice, pulmonary embolism, intestinal obstruction, staple line bleeding, and ileal perforation (Table 1) [4].

Table 1 Grades of complications after SASI bypass [4]

Grade of complication	Type of complication	Number (%)
Grade I	Bilious vomiting	32 (5.8%)
	Diarrhea	15 (2.7%)
Grade II	Stoma ulcers	3 (0.54%)
Grade III	Staple line bleeding	1 (0.18%)
	Intestinal obstruction	1 (0.18%)
	Ileal perforation	1 (0.18%)
	Calcular obstructive jaundice	2 (0.36%)
Grade IV	Pulmonary embolism	1 (0.18%)

The most frequently reported complication after the SASI bypass was bilious vomiting. Bile reflux seems to be a common phenomenon in patients with a single gastroileal anastomosis, MGB and even RYGB [49] but even if dumping or biliary reflux is intractable, it can be simply reversed or revised to Braun's reconstruction [45]. In Mahdy et al.'s study, bilious vomiting and diarrhea were treated conservatively with fluids and medications. Stomal ulcers were managed with proton pump inhibitors, and calcular obstructive jaundice was treated with endoscopic retrograde cholangiopancreaticography (ERCP)and stone extraction, whereas a staple line bleeding, intestinal obstruction, and ileal perforation required surgical intervention. One patient who developed a pulmonary embolism was admitted to the ICU and was treated with intravenous fluids, anticoagulant medications, and thrombolytic therapy [4].

While most bariatric surgical procedures can be associated with nutritional deficiencies (as were reported for SG with median deficiency rates of iron, zinc, vitamin D, and vitamin B12 (9%, 20%, 35.5%, and 11.7%, respectively)) [50], SASI bypass has only a statistical decrease in serum albumen, which has proven to cause no clinical significance as serum albumin levels were still within the normal laboratory range so that none of the patients developed protein malabsorption after the SASI bypass [4, 43]. On the contrary, Salama et.al reported normal serum albumin and hemoglobin levels, with calcium deficiency in 2 cases of his study which improved with oral supplements [43]. On the other hand, Mahdy et al. demonstrated that vitamin D levels showed a significant increase at 1 year after the SASI bypass, which was explained by patients' compliance with systemic intake post operatively [33]. All options for weight regain after sleeve are associated with high failure and nutritional deficiency because they depend on malabsorption. SASI bypass, however, depends on modulation of gastrointestinal hormones without causing malabsorption, with easy conversion to the normal anatomy and a low morbidity rate.

9 Take Home Message

The ideal metabolic operation is one with high efficacy, cause resolution of comorbidities, easy to perform and have an easy exit strategy. The SASI bypass is an effective and safe bariatric procedure, with low and minor complication rate that can be added to suboptimal or failed SG to combat weight regain. It has also shown remarkable improvement in obesity-related comorbidities, namely T2DM and GERD.

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