

Sleeve and sleeve plus

Chih-Kun Huang, Chia-Chia Liu, Ming-Che Hsin, Yen-Chou Chen

Body Science and Metabolic Disorders International (B.M.I) Medical Center, China Medical University Hospital, Taichung, Taiwan

Contributions: (I) Conception and design: CK Huang; (II) Administrative support: MC Hsin; (III) Provision of study materials or patients: CK Huang; (IV) Collection and assembly of data: CC Liu; (V) Data analysis and interpretation: YC Chen; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Chih-Kun Huang. Body Science and Metabolic Disorders International (B.M.I) Medical Center, China Medical University Hospital, 6F, No. 2, Yude Rd., North Dist., Taichung, Taiwan. Email: dr.ckhuang@hotmail.com.

Abstract: Obesity is an epidemic issue that will cause type 2 diabetes, cardiometabolic diseases, stroke, osteoarthritis, sleep apnea and some kinds of cancer. These diseases may be lethal and usually cause high cost of medical expenditure. Many studies have reported that bariatric surgeries are much superior than intensive medical therapies in reaching therapeutic goal of weight loss and resolution of co-morbidities. The golden standard procedure, laparoscopic Roux-en-Y gastric bypass (LRYGB) has most satisfied resolution rates of metabolic diseases especially in type 2 diabetes mellitus (T2DM). However, needs for long-term supplement of vitamins and higher rates of complications makes bariatric surgeons to invent other modified surgical techniques. Due to short learning curve and satisfied surgical results, laparoscopic sleeve gastrectomy (LSG) now is worldwide accepted. However, comparing with LRYGB, LSG could not achieve the same remission rates of obesity-related comorbidities especially T2DM. Therefore, a new surgical procedure: loop duodenojejunal bypass with sleeve gastrectomy (LDJB-SG) has been invented. Today, we review the sleeve gastrectomy and LDJB-SG from basic surgical methods to possible mechanisms: weight-dependent and weight-independent mechanisms (intestinal inversion and change of gastrointestinal hormones) to discuss the roles of these two surgical procedures in bariatric surgery.

Keywords: Sleeve gastrectomy; sleeve plus; loop duodenojejunal bypass with sleeve gastrectomy (LDJB-SG); bariatric surgery; diabetes mellitus type 2 (T2DM)

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Introduction

Obesity is an issue of epidemic concerns affecting all ethnicities, ages, and genders (1-3). In United States, about 35% of the adult population are considered to be obese (1,3). Obesity has strong relationship with numerous and various comorbid conditions such as diabetes, stroke, cardiometabolic diseases, obstructive sleep apnea (OSA), joint diseases (osteoarthritis), gallbladder problems and many cancers, as well as negative effect on quality of life (1-3). The rise of various bariatric surgeries have been well established in recent decades, especially for patients with morbid obesity, in terms of weight reduction, obesity-associated co-morbidities, and quality of life

have been proved the effectiveness and safety (1,4-7). In addition, recent evidence has also shown bariatric surgery achieved better long-term survival than conventional medical treatments (8-12). The most common bariatric surgery procedures include laparoscopic Roux-en-Y gastric bypass (LRYGB), laparoscopic sleeve gastrectomy (LSG), laparoscopic adjustable gastric band (LAGB), and laparoscopic bilio-pancreasatic diversion with duodenal switch (LBPD-DS).

We acknowledge that the LRYGB (*Figure 1*) is the worldwide-accepted golden standard surgery for morbid obesity and type 2 diabetes mellitus (T2DM). However, its long-term complications such as marginal ulcer, dumping syndrome, iron deficiency anemia, Osteoporosis *et al.* make

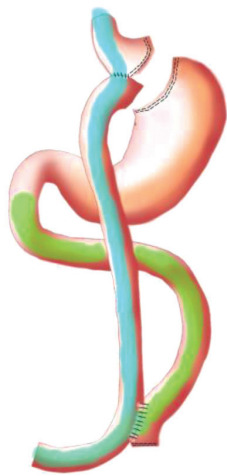


Figure 1 Roux-en-Y gastric bypass.



Figure 2 Sleeve gastrectomy.

the birth of the LSG, which now is the primary and basic bariatric procedure. Sleeve gastrectomy is designed to be the restrictive component of BPD-DS in the beginning. For those high risk patients (ex. super-obesity or poor cardiopulmonary function patients), LSG was used as the first-step surgery prior to the two-stage procedure. It now becomes the primary one-step procedure (13-15). The simplicity of the procedure, effectiveness of weight loss, less postoperative morbidities and prominent resolution of comorbidities makes LSG become so popular. Although LSG has satisfied weight loss comparing with intensive medication therapy, LRYGB is still better than LSG on many aspects such as the resolution of T2DM and results of weight reduction. In order to reach a comparable results

with LRYGB without its disadvantages, we invented a new procedure: loop duodenojejunal bypass with sleeve gastrectomy (LDJB-SG).

LSG

LSG (*Figure 2*) provides desirable and quick weight loss with less vitamin deficiency (16). It involves only vertical resection of stomach of greater curvature side and creates a longitudinal and high pressured gastric tube.

Operative techniques

Mostly surgeons place 4–5 ports during performing LSG. Via the subxiphoid incision, a Nathanson's liver retractor or our liver suspension technique are used to lift left hypertrophic liver (16,17). The gastroepiploic vessels are divided along the greater curvature. It begins 4–6 cm from the pylorus to the angle of His and left crus of diaphragm. And then along with a 38 French bougie, a vertical gastrectomy is performed with endoscopic staplers. The resected stomach is extracted via umbilical port. Single-incision trans-umbilical LSG also could be performed, which was associated with better cosmetic appearance, less need for analgesics, relatively scarcer complaints of postoperative pain, and more pleased over-all patients satisfaction compared with conventional multi-port LSG (17,18).

Weight loss results of LSG

Recent few years, more literatures are published to report weight loss results between intensive medication treatment, LSG and LRYGB. In the randomized controlled trial of Surgical Treatment and Medications Potentially Eradicate Diabetes Efficiently (STAMPEDE) reported by Schauer *et al.* showed surgical groups had better percentage weight loss result from baseline, with weight reductions of $24.5\% \pm 9.1\%$, $21.1\% \pm 8.9\%$ and $4.2\% \pm 8.3\%$ in the gastric-bypass group, sleeve-gastrectomy group and medical-therapy group respectively ($P < 0.001$ for both comparisons). And there was no statistically significance between LSG and LRYGB groups on % excess weight loss (%EWL) for 3 years follow-ups (19). Lee *et al.* found in veterans population, LRYGB achieved the most weight loss in kg, body mass index (BMI) reduction, %weight loss, and %EWL, followed by the LSG procedure, and AGB yielded the least weight loss (1). A 4-year weight change of multisite

clinical veteran cohort study who underwent LRYGB, AGB and LSG showed weight loss compared with baseline BMI were 27.5%, 10.6%, 17.8% respectively (20) which revealed LRYGB had better weight loss. Other previous studies (21-24) also had the same conclusions of shorter-term weight loss (1-3 years).

For long-term weight regain, 30.5% for AGB; 14.6% for SG and 2.5% for LRYGB were observed (20,25). Arman *et al.* (26) recently showed a 11-year-follow-up outcomes of LSG, despite of the low follow-up rates (only 59%), the % excess body mass index loss was 62.5% in 11+ years. In our center, 63.71% EWL was reported at postoperative year 5 (27). Meta-analysis data also suggested that LRYGB resulted in a greater %EWL than LSG. It should be the size of the sleeve, the amount of antrum retained, and the amount of fundus resected that account for the variable weight loss results of LSG (28).

As for adolescent or young adult group, Maffazioli *et al.* found there was no statistically significant difference on body weight loss or weight regain after following up for 18 months in both LRYGB & LSG groups (29) which was consistent with Inge *et al.* (30) and Cozakov *et al.* (31) studies.

LSG has adequate and satisfied weight loss in both short-term and long-term results. Although LRYGB may showed superior in weight loss, its need of long-term vitamins supplement, nutritional and metabolic complications make patients backward.

Co-morbidities resolution after LSG

Morbid obesity attributes to many serious co-morbidities such as T2DM, dyslipidemia, sleep apnea, hypertension, osteoarthritis, blindness, amputation and gastro-esophageal reflux disease (GERD) (28). There are many therapies for morbid obesity including intensive medical therapy, behavior change, and even acupuncture, the alternative treatment. However, none of them can effectively resolve these problems or can provide the sustained success (19,28). Bariatric surgery results in not only the excellent outcome of sustained weight loss but also the advantage of comorbidities remission (32). More recently, many studies implicate bariatric surgery as a metabolic surgery because it also provides remission or improvement in T2DM in mildly obese patients (33-36).

Diabetes mellitus resolution result

In STEMPED trial, at 3 years, the target glycated

hemoglobin level of 6.0% or less was achieved in 5%, 38%, 24% of the patients in the medical group, gastric-bypass group ($P<0.001$) and sleeve-gastrectomy group ($P=0.01$) respectively. There was also no statistically significant difference on LSG and LRYGB groups (19). According to Swedish Obese Subjects (SOS) study which comparing bariatric surgery with conventional medical treatment: the higher rates of diabetes remission at 2, 10 and 20 years and less long-term complications including total-cause mortality and major cardiovascular events were found in surgical treatment group (12,19,37,38). Some literatures showed LRYGB was still superior to LSG on resolution of insulin secretion and sensitivity. It's also be the LRYGB, not the LSG, that reduce more truncal fat compared with subcutaneous fat (39). In our center experience, a 5-year-follow up of LSG showed 66.66% resolution of T2DM by definition of lesser or no use of diabetes medications (27). Nossio *et al.* found that for the morbid obese T2DM patients, in both LRYGB and LSG groups in terms of different hormonal and metabolic mechanisms involving in weight loss and T2DM remission one year after surgery, there were almost the same improvements of glucose profile in these two procedures. Weight loss is the key point of diabetes remission in morbidly obese T2DM patients one year after surgery (40).

It can't be denied that weight loss changes the adipotoxicity in human body is the main cause of improvement of metabolic diseases in the early phase. However, there are more current data suggest that hormonal modulations, not weight loss alone, contribute to the beneficial effect of bariatric surgery for T2DM (41). LRYGB and LSG both change the islet function activity by altering enteroinsular axis. Gut hormones changes after LRYGB on ghrelin, peptide YY (PYY), and glucagon-like peptide-1 (GLP-1) are well documented (32). Similar to LRYGB, although to a lesser degree, LSG increases GLP-1 responses to meal ingestion (39,42) whereas gastric banding have no effect on postprandial glucose excursion or insulin and gut hormone responses (43). LSG indeed can improve T2DM to some extent.

Cardiovascular related markers resolution result

Hypertension

Among obese population, the most common co-morbidity is hypertension. Adipose tissue deposition can impair renal function and lead to blood pressure change (44). The possible mechanism is the altered neuroendocrine response, renin-angiotensin-aldosterone (RAA) system. LSG and

LRYGB can result in a significant blood pressure reduction due to decreased cardiac stroke volume and lipotoxicity to the kidney after weight loss (45). In our center experience, a 5-year follow ups of LSG showed 100% resolution of hypertension (27). Otherwise, Li *et al.* meta-analysis showed the LRYGB is still more favored in remission rate of hypertension than LSG (28).

Dyslipidemia

From STEMPED trial, comparing medical and surgical treatments, 3-year-follow up showed much better sustained lower triglyceride and higher high-density lipoprotein (HDL) cholesterol levels in both LRYGB & LSG groups (19). In our 5-year-follow up of LSG, 50% resolution of hyperlipidemia was noted (27). Lee *et al.* reported 73.7% remission of dyslipidemia by a multicenter retrospective comparative cohort study of LSG (46). Li *et al.* meta-analysis showed 49.5% remission of hypertension of LSG compared with 71% of LRYGB (28).

OSA

Obesity is the most significant predisposing factor for OSA. According to de Sausa *et al.*, elevation of 6 kg/m² in BMI increases four times risks of developing OSA (47). The possible pathophysiological mechanisms of OSA are: (I) obese patients with OSA have 42% more fat in their neck, resulting in pharyngeal lumen narrowing; (II) leptin resistance which has a key role on controlling body-weight and respiratory center (48-50). A systemic review and meta-analysis made by Buchwald *et al.* reported OSA was resolved in 85.7% of obese patients with OSA (21). LRYGB is still the predominant choice of the surgery that has a better resolution rates than LSG (21,50,51). In fact, many literatures (50-53) discussed the differences in surgical efficacy maybe explained by weight-dependent and weight-independent effects (acronym BRAVE+ I: bile flow alteration, restriction of gastric size, anatomical gut rearrangement and altered flow of nutrients, vagal manipulation and enteric gut hormone modulation + improvement of systemic inflammation, such as soluble TNF-receptor 2, leptin which can increase neuromuscular control of pharyngeal diameter). Recent study done by Amin *et al.* revealed increase orexin levels after bariatric surgery is another possible weight-independent mechanism of early improvement of OSA (54). Both LRYGB and LSG can improve OSA in early phase of postoperative period (55). Dilektasli *et al.* reported sleeve gastrectomy can improve excess daytime sleepiness and sleep quality 6 months after the surgery (56). No matter what kinds of bariatric surgeries

is chosen, OSA is a strong indication of bariatric surgery.

Nonalcoholic fatty liver disease (NAFLD)

NAFLD is an important comorbidity of obesity and nonalcoholic steatohepatitis (NASH) is a precursor to the development of liver cirrhosis that may necessitate liver transplantation in the long run (57). Many literatures in recent years pay emphasis on the bariatric efficacy of improvement of NAFLD (29,58). There are no definite results on which type of surgeries has the best resolution rate. However, LSG seems to have a better improvement of liver function when comparing with LRYGB postoperative 6–12 months to date. According to Billeter *et al.*, after 1 year follow up, aspartate aminotransferase (AST) and alanine aminotransferase (ALT) levels were both reduced in LRYGB and LSG groups. However, it's the LSG group that has much lower AST and ALT levels than LRYGB and completely resolved the biochemical signs of NAFLD 12 months after the surgery (41% patients still had elevated ALT levels in LRYGB group) (58). Praveen *et al.* reported histological improvement of NAFLD within postoperative 6–8 months for both SG and LRYGB. However, SG appears to have a better effect on liver histology although this result did not reach statistical significance (59). In addition to weight loss, many experiments suggest change in bile acid metabolism and signaling through farnesoid-X receptor (FXR) which affects fatty acid metabolism of the liver may be the possible explanations of LSG on improvement of NAFLD (60-62).

Complications of LSG

There are early and late complications of LSG. When comparing with LRYGB, LSG is still a procedure with lower readmission and re-operation rates. Staple line leaks, bleeding, and strictures are the commonly reported complications following LSG. Shi *et al.* reported average rate of LSG complications in a systemic review: approximately 3.57% of bleeding rate, 12.1% of major complications, 1.17% of leak rate and mortality rates between 0 and 3.3% (63). International Sleeve Gastrectomy Expert Panel Consensus Statement 2011 [38] showed: 1.06% of leak rate, 0.35% of stricture with 1.05–1.85% of overall conversion rate and 3.66–5.1% of postoperative gastric fistula (64). LSG which as a longer staple lines has comparable leak rates to LRYGB which has shorter ones (65).

Gastroesophageal reflux disease (GERD) is the most

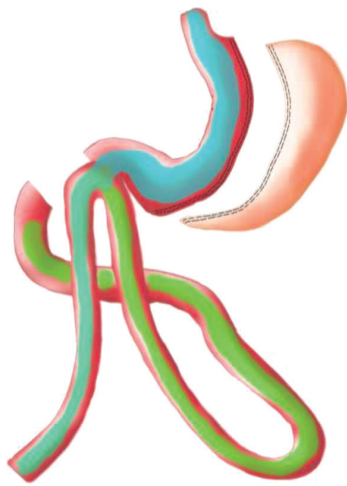


Figure 3 Loop duodenojejunal bypass with sleeve gastrectomy.

common chronic complications complained by the patients and usually need to do revisional surgery which LRYGB is usually chosen. About 11–33% patients have GERD reflux in long-term follow ups (66) after LSG. Until now, there were no sufficient evidences to show the relationship between LSG and GERD. Chiu *et al.* (67) reported a systemic review showing no conclusive relationships on LSG to GERD. Keidar *et al.* implied when a relative narrowing of the middle stomach combined with a dilated upper stomach after the LSG, GERD may happen even without any complete obstruction (68). This functional obstruction would result in severe esophageal dysmotility with reflux symptom. Patients may reduce the incidence of GERD after LSG when they concomitant repair of hiatal hernia (HH) during the LSG operation (69). Preoperative evaluation of hiatal defects and repair of it during the LSG is recommended (70). For the small hiatal defect which is easily missed during preoperative panendoscopy examination, can be revealed and repaired easily when the surgeon remembers to exam the crura during LSG procedure and dissects left crura during dissection angle (66).

Why we need more in addition to LSG about diabetes resolution

LSG was once considered a restrictive procedure, but this presumption has recently come under scrutiny (71). It is found to be involved in “restriction”, “absorption” and “hormone change”. “Foregut” and “Hindgut” theories, recently even the midgut, can somehow give

us possible explanations of LSG results. LSG resect the fundus of stomach where ghrelin is the main hormone to be secreted, which dramatically diminished and also increase the counter-hormone “obestatin” level in the early postoperative time (72). The counter-reaction of ghrelin and obestatin combined with decreased leptin may cause body to reduce appetite and utilize blood glucose effectively (73). Also postoperatively 1 year-follow up showed increase of CCK which also play a role in LSG on weight loss and sugar control (42). Up-regulated secretion of incretins (GLP-1, PYY), the glucose-dependent insulin enhancer, which were elevated while rapid delivery of partially digested food into distal intestine, combines with other changes mentioned above are important reasons to improve glucose tolerance after LSG (73–76).

Reduction of digestion was due to combination of restriction, the “appetite suppressive” effect from resection of the ghrelin-rich fundus, faster gastric emptying and decreased gastric acid secretion (77,78). Hormonal changes of LSG included antidiabetic effects of GLP-1 and PYY (79,80), which are not seen with the purely restrictive procedures like gastric banding. According to these studies, LSG can achieve satisfied body weight loss and T2DM resolution results. Otherwise, it is still inferior than LRYGB, which involves more physiologic mechanism of bypassing duodenum and proximal jejunum. To achieve better T2DM resolution, add foregut exclusion to sleeve gastrectomy (sleeve plus) might be an essential modification.

Sleeve plus: LDJB-SG

LRYGB and BPD-DS are procedures with higher rates of T2DM remission and long-term complications (81). The aim of metabolic surgery is to produce remission of T2DM with more physiological aspects and minimal morbidity and mortality. In our center, LDJB-SG (*Figure 3*), a novel surgical procedure was invented as a proposed technique for treatment of T2DM to reach the goal of metabolic surgery (82).

Operative techniques

Under general anesthesia, a 5-port laparoscopic surgery was used to access the abdominal cavity. We then performed a standard sleeve gastrectomy with endostaplers. After ensuring hemostasis, a stay suture was placed at the distal end of SG for counter-traction and better visualization of the first part of the duodenum. Two centimeters distal

to the pylorus, we did the dissection of the duodenum. For firing the stapler, we need to use a tape to place for traction after the dissection of duodenum. We transected duodenum 2 cm from the pylorus, taking care not to injure the common bile duct (CBD), pancreas, and major vessels in the area. And then we measured 2–300 cm of the jejunal loop from the ligament of Treitz. We then performed side to side isoperistaltic, totally hand-sewn, one layered duodeno-jejunal anastomosis with absorbable sutures. After the anastomosis, we placed one anti-torsion suture in the antrum and upper jejunum, 4 cm proximal to the duodenojejunosomy. We then repaired the Peterson defect with a continuous non-absorbable suture. We put one Jackson-Pratt drain behind the duodenojejunal anastomosis reaching the sleeve and end the procedure (82).

Advantages of LDJB-SG

Exclusion of duodenum may ease the abnormal glycemic control and insulin resistant. Scientists found proximal bowel diversion, which was done on rat models, would not decrease food intake or weight loss but may improve diabetes instead. As previous elucidation, that's the reason why LSG only resolved partial T2DM. Rubino *et al.* demonstrated when bypassing duodenum and proximal jejunum, amelioration of T2DM will occur without any change on food intake, body weight, malabsorption, or nutrient delivery to the hindgut (83).

LDJB-SG has higher satisfied T2DM resolution rates than LSG (remission rate for 1 year follow up: 62% *vs.* 32%) (84). For diabetes patients, surgery preserving the pylorus may cause delaying gastric emptying and then reduce postprandial glucose excursions (85,86). LDJB-SG is a good option for revision when intractable dumping syndromes happened after LRYGB (87). LDJB-SG also eliminates the risk of remnant gastric cancer, an important issue in Asia where gastric cancer is very common (88). Based on our experience, the resolution of co-morbidities was similar in both LDJB-SG and LRYGB for BMI <35 kg/m² T2DM patients at postoperative 1 year. LDJB-SG has longer operative time and length of stay than LRYGB, however, it has no inferior rate than LRYGB on postoperative one-year improvement of body weight loss, fasting plasma glucose and %HbA1c. The level of HOMA-%B at 12 months was even significantly higher in the LDJB-SG than in the LRYGB (89). However, further studies on change of gut hormones and long-term results

compared with RYGB, LDJBSG is still needed to be investigated in the future.

Conclusions

LSG has gradually taken place LRYGB as the main bariatric surgery in the world. And sleeve plus surgery, such as LDJB-SG, will become the main surgical procedure in treating obesity with T2DM, because of better resolution than LSG, but less complications than LRYGB.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at <http://dx.doi.org/10.21037/ales.2017.01.10>). CKH serves as an unpaid editorial board member of *Annals of Laparoscopic and Endoscopic Surgery* from Jul 2016 to Jun 2018. The other authors have no conflicts of interest to declare.

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