



Laparoscopic bariatric surgery-current trends and controversies

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Abstract: Although the origins of bariatric surgery to treat obesity can be traced back to the 1950s with the jejunioileal bypass, which is considered a malabsorptive bariatric procedure, its practice remained in obscurity until two things happened. First, obesity becoming a pandemic disease state with life threatening comorbidities such as diabetes, hypertension, sleep apnea, dyslipidemia and metabolic syndrome, resulting in a higher risk for premature death. Second, the introduction, development, and refinement of minimal access surgical techniques along with newer laparoscopic stapling devices. With the advent of laparoscopy in the 1980s, bariatric surgery began to be performed through minimally invasive techniques. The purpose of this article is to describe the science and evolutionary development of various laparoscopic bariatric surgical techniques and the associated surgical anatomy.

Keywords: Bariatric surgery; laparoscopy; metabolic surgery; diabetes surgery

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Introduction

The first laparoscopic procedures for obesity were performed in the early 1990s. Broadbent and colleagues first successfully placed a non-adjustable gastric band in a patient on September 10, 1992 in Australia, and published their preliminary results in 1993 (1). After initial animal experiments in 1992, Belachew and colleagues placed the first laparoscopic adjustable band in a human on September 1, 1993 in Belgium (2).

The first laparoscopic vertical banded gastroplasty (VGB) was performed by Hess and Hess on July 29, 1993 in Bowling Green, Ohio (3). However, only 2 laparoscopic VGBs were performed before changing to the duodenal switch (DS) procedure they were developing. Just 3 months later, Wittgrove and Clark performed the first laparoscopic Roux-en-Y gastric bypass (RYGB) procedure in October, 1993, and published their results on 500 patients in 2000 (4). Gagner performed the first laparoscopic DS procedure in 1999 (5).

Johnston and colleagues from Leeds, United Kingdom, developed a simpler “Magenstrasse and Mill” (M & M) procedure that would avoid the use of implanted foreign material such as bands and reservoirs and overcome the disappointing results of the VBG procedure and the morbidity of the gastric bypass (6). At first, a 40-French bougie was used, but because of unsatisfactory weight loss, the size was reduced gradually, and they found that a 32-French bougie resulted in a 63% excess weight loss at 3 years. In 1999, McMahon performed the M & M operation laparoscopically in Leeds, and in 2000 he performed the first laparoscopic sleeve gastrectomy (SG) in UK while Gagner performed it simultaneously in US (5,7). Modifications were made to the original procedure in subsequent years to simplify the technique, improve weight loss maintenance, and to facilitate the evolution of laparoscopic SG (8).

A worldwide survey on bariatric surgery published in 2015 showed that 468,609 bariatric procedures were performed worldwide in 2013, of which 95.7% were carried out laparoscopically. The most commonly performed

Table 1 Guidelines & eligibility criteria for bariatric surgery

Eligibility criteria	Age	BMI only	BMI with comorbidities	Additional points
NIH guidelines (12)	NA	≥40	≥35	–
IFSO guidelines (14)	≥18 or ≤60 years	≥40	BMI ≥35 with comorbidities; BMI 30–34.9 with recent onset T2DM	Previous non-surgical failed weight loss attempts; patients are motivated and are free of significant psychological disease
Asia-Pacific region (13) (ACMOMS)	≥18 or ≤65 years	≥35	BMI ≥32 with comorbidities; BMI ≥30 with central obesity WC ≥80 cm (females) WS ≥90 cm (males) with at least two comorbidities; BMI ≥27.5 kg/m ² with inadequately controlled DM (HbA1c ≥7)	Proven failure of nutritional and behavioral therapy; motivated and able to provide a valid consent, are willing to undergo periodic inspections and follow an established dietary regime; absence of major contraindications (very high operative risk, limited life expectancy due to illness, severe cirrhosis, alcohol abuse, major psychiatric illness); long standing obesity ≥5 years
IFSO APC	≥18 or ≤65 years	≥35	BMI ≥30 with comorbidities; BMI ≥27.5 kg/m ² with inadequately controlled DM (HbA1c ≥7)	Failed weight loss attempts; no major psychiatric illness; motivated
International Diabetes Organizations	≥18 or ≤60 years	≥40 and Asians ≥37.5	BMI ≥35 (≥32.5 for Asians) with comorbidities; BMI ≥30 (≥27.5 for Asians) kg/m ² with inadequately controlled DM (HbA1c ≥7)	–

NIH, National Institute of Health; IFSO, International Federation for Surgery of Obesity and Metabolic Disorder; ACMOMS, Asian Consensus Meeting on Metabolic Surgery; WC, Waist circumference.

procedure in the world was RYGB, 45%; followed by SG, 37%; and adjustable gastric banding (AGB), 10%. Most significant was the rise in popularity of SG from 0 to 37% of the world total from 2003 to 2013, and the decline in AGB of 68% during its peak in 2008 to 10% in 2013 (9). The proportion of SG increased from 3% to 54% between 2008 to 2014, while RYGB decreased from 52% in 2008 to 32% by 2014 (10). Older bariatric surgical procedures, including jejunocolic bypass, jejunoileal bypass, vertical banded gastroplasty, and biliopancreatic diversion, are no longer performed. Biliopancreatic diversion with DS is still performed in select centers in much smaller number (<1.5% of all bariatric procedure) (9).

Over the years many newer laparoscopic bariatric and metabolic procedures have been developed and modified like greater curvature plication (GCP), mini gastric bypass (MGB), duodenojejunal bypass (DJB), ileal interposition (II), transit bipartition (TB), and jejunoileal anastomosis (JIA).

Patient selection

The WHO classifies obesity, as having BMI ≥30 kg/m² (overweight if BMI ≥25 kg/m²). Caucasians are known to

have much lower body fat percentage, waist circumference (WC) and waist-hip ratio (WHR) as compared to Asians, where central obesity is highly prevalent leading to metabolic syndrome even at normal levels of BMI (11). Bariatric surgeries have been standardized worldwide for many years through an influential National Institutes of Health (NIH) consensus statement (12), which has been revalidated in many studies. From the beginning the emphasis has been on BMI as a selection criteria for surgery, whereas worldwide debate suggests that WC, WHR, comorbidities, quality of life indicator especially functional restriction should be important considerations along with BMI (13,14) (Table 1,2).

Preoperative evaluation

Patients who are considered for bariatric surgery benefit most from individualized choice of procedure through proper evaluation of medical history and all comorbidities (Table 2); it is important to detect occult pathology through established diagnostic tests (Table 3). Various scoring tools can be used to assess the surgical risk, establish the severity of obesity and predict surgical outcome (15-17) (Table 4).

Table 2 Specific comorbidities

Hypertension
Ischemic heart disease
Type 2 diabetes
Obstructive sleep apnea syndrome
Obesity syndrome/hypoventilation (Pickwickian syndrome)
Non-alcoholic fatty liver disease and steatohepatitis
Dyslipidemia
Gastroesophageal reflux disease
Asthma
Venous stasis disease
Severe urinary incontinence
Disabling arthropathy
Severely reduced quality of life

Operating room setup

A steep reverse Trendelenburg position of operating table is adopted with patient lying supine. Some surgeons prefer split leg (French) position to stand between the legs while operating, whereas others prefer to stand on patient's right side. Prophylaxis against deep vein thrombosis necessitates usage of graduated compression stockings for the lower limb along with a sequential compression device.

Postoperative care

Patients are kept nil by mouth under supervision of critical care specialist and motivated for early ambulation, usually 6–8 hours after surgery. Meanwhile compression stockings and low molecular heparin are continued along with spirometry and chest physiotherapy. On first postoperative day patients are allowed clear sips of liquid once every 10–15 min. Patients are discharged on 2nd or 3rd postoperative day with oral dispersible medicines depending on general condition, hydration, and on drain status.

SG

Introduction

Recently SG has gained worldwide popularity over the gold standard operation, the RYGB due to safety and lesser long term nutritional issues. Barrett's esophagus is the only

absolute contraindication for SG. There is enough long term data to suggest SG is equivalent to RYGB in terms of weight loss and diabetes remission; while some studies show a significant difference in diabetes remission in favor of bypass surgeries (18-20).

Indications

- (I) Morbidly obese patients satisfying the criteria for bariatric surgery;
- (II) First stage or standalone procedure for super obese;
- (III) High risk patient where duration of procedure affects morbidity and mortality;
- (IV) Potential/future organ transplant candidates.

Contraindications

- (I) Barrett's esophagus (Relative contraindication);
- (II) Malignancy;
- (III) Liver cirrhosis with portal hypertension;
- (IV) Alcohol abuse.

Surgical anatomy

After inserting 32 to 38 French gastric calibration tube (GCT) up to gastroesophageal (GE) junction, a window is created on greater curvature using any energy source like Ligasure or Harmonic just diagonally opposite to "Crow's foot" at the avascular plane close to stomach wall, so as to enter the lesser sac. This dissection is carried out cranially up to GE junction exposing left crus and caudally up to pylorus. It is very important to free posterior gastric wall so as to avoid twisting or "cork-screw" after SG. The stapler is placed slightly away from bougie maintaining at least 2 cm from incisura edge so as to avoid stricture. The sleeve is created by sequential firing; last fire should be at least 1–2 cm away from GE junction with no left over fundus (*Figure 1*).

Surgical outcome

Weight loss

The percentage excess weight loss (% EWL) in laparoscopic sleeve gastrectomy (LSG) after first year can vary from 54% to 78% (21,22). This variation in first year outcomes may be due to variations in surgical technique, different bougie sizes, ethnic and/or dietary variations. One study declared 86% EWL at 5 years having a follow up of 90% (Gastroscope used as bougie and first stapler fired at 3 cm

Table 3 Investigations

Investigations	All patients	Selected patients
Blood	Complete blood picture & blood group; Kidney function tests (BUN, creatinine, electrolytes); Liver function tests, lipid profile; Thyroid function tests; Fasting and postprandial blood sugars; Fasting serum insulin; Serum calcium, vitamin D3 and B12; Sr. iron, transferrin saturation, Sr. ferritin, total iron body concentration; Clotting screen (PT, APTT, INR); Fasting serum cortisol at 8 am; Viral markers	Anti-GAD for young diabetics (Glutamic acid decarboxylase) antibodies; Islet cell antibodies (ICA); C-peptide-fasting and stimulated
Cardiac	Blood pressure; ECG; 2-D echo; Dobutamine stress test	–
Respiratory	Oxygen saturation	Pulmonary function test; Arterial blood gas; Polysomnography
Imaging	Chest X-ray; Ultrasonography abdomen; Doppler for leg veins	Computed tomography; Doppler for Carotid arteries
Endoscopy	Upper GI endoscopy with Rapid urease test (ASMBS does not recommend routine endoscopy but ASGE recommends it in all patients); Geographical areas with high incidence of carcinoma stomach; Past history of Acid peptic disease; High suspicion of GERD or Hiatus hernia	–

from pylorus) (23). There are multiple reports showing >50% EWL at and beyond 5 years (9,24), whereas a recent review reported 62.3%, 53.8%, 43%, and 54.8% EWL at 5, 6, 7 and 8 years respectively (24).

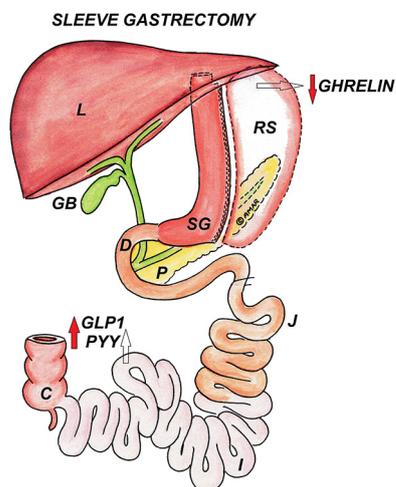
Diabetes resolution/remission

The factors influencing diabetes remission/resolution after bariatric surgery are multiple, like duration of

diabetes, elevated glycated hemoglobin (HbA1c), insulin treatment, older age, and poor pancreatic function (Low C-peptide) (25). In a systematic review of 673 patients having a mean follow-up of 13.1 months (range, 3–36 months), 66.2% had remission, 26.9% had improvement, while 13.1% showed no change. Reduction in blood glucose was 88.2 mg/dL while HbA1c decreased by 1.7% (26). In another systematic review (n=402) on long term outcomes

Table 4 Obesity scoring systems

Scoring tools	Description
Assessment of obesity related co-morbidities scale (AORC) (15)	Score 0–5, depending on comorbidities
Edmonton obesity scoring system (EOSS) (16)	Classifies obesity in five stages 0–4, considering physical symptoms, psychological symptoms, and limitation of functional aspects. Shown to be more accurate predictor of total mortality than BMI levels
Obesity surgery mortality risk score (OS-MRS) (17)	Uses five variables (BMI >50 kg/m ² ; male gender; hypertension; history or risk of DVT; age >45 years); the presence of ≥4 risk factors has mortality risk of 7.5%, whereas score of 0–1 and 2–3 has mortality risk of 0.31% and 1.9% respectively

**Figure 1** Laparoscopic sleeve gastrectomy.

after SG in T2DM, 60.8% patients had remission at 5 years with a significant decrease in T2DM prevalence (20.5%). Mean plasma glucose decreased from 170.3 to 112.0 mg/dL and HbA1c from 8.3% to 6.7% at 5 years (27).

Controversial issues

Bougie size

Varying rates of success and long-term weight control seem to be influenced by differing bougie sizes. The 4th international consensus summit on SG recommended 36 French bougie (28), whereas another panel expert concluded that 32–36 French is optimal (29). However, in a large meta-analysis, greater weight loss was seen with a bougie size of less than 40 French during the first six months though the difference in weight loss was not significant at the end of 36 months. Another important outcome of this study showed a leak rate of 2.5%, 1.7% and 0.9% with bougie size of <40 French, 40–49 French and >50 French respectively (30).

Distance from pylorus

There was lack of consensus in the international expert panel regarding distance from pylorus to begin sleeve resection (32% voted for 4–5 cm, 27% for 3–4 cm and 23% for 5–6 cm) (29). There is no strong data to decide optimal antral resection, where some believe that a distance greater than 4 cm from pylorus preserves the antral pump and improves gastric emptying with reduced intraluminal pressure. However, authors recommend SG resection at 3 to 4 cm from the pylorus.

Reinforcement

Chances of bleeding and leaks are expected to decrease with staple line reinforcement. The suggested methods of reinforcement are oversewing, buttressing material, omental flap, and glue along staple line. Publications from some authors report debatable results, with reinforcement leading to higher leak rate (0.96% vs. 0.65%) with expected reduction in rate of bleeding (0.75% vs. 1.00%) (31). A comparison of various methods of reinforcement indicates a clear superiority of absorbable polymer membrane for buttressing, leading to decrease leak rates in comparison to oversewing, bioabsorbable peristrip reinforcement, or no reinforcement (32).

Complications

These are summarized in *Table 5* (33–36).

RYGB

Introduction

RYGB has been considered the “gold standard” in bariatric surgery. In 2013, the most commonly performed bariatric procedure worldwide was RYGB (9). Creation of a small gastric pouch along with bypass of duodenum and proximal

Table 5 Complications

Complication	LSG (33-36)	RYGB (36-40)	LAGB (36,41-43)	BPD (44)/BPD-DS (36,45)	MGB (46-48)	SADI-S/LDJB-SG (49)	II-SG (50,51)	SG-TB/SG-LB (52,53)	LGP & LAGBP (54,55)
Overall mortality rate	0.11-0.36%	0.04-0.16%		0-1.4%		0.08-0.2%	0.2%	0.2%	0
Overall complication rate							7.75%	6-12%	LGP:8%
VTE/PE	0.14%	0-1.3%		0.3%				2%	
Other complications	Abscess: 0.7%	Internal hernia/obstruction: 5%	Erosion: 1-2%; port related: 6%	Nutrient deficiency: 33%; obstruction: 0.3%-2.4%	Bile reflux: 1-2%			Reversal of procedure: 2%	Gastric fold herniation: 2.2%
Port-site hernia	0.14-1%	0.2%							1%
Hemorrhage	1-6%	1-2%		0.3%		1.9%		2%	1.4%
Leak	Up to 5%	1-2%		1-3.5%	0.6-1.6%	Total: 1.9% (SG: 1.1%, DS: 0.6%, DEA: 0.2%)		2% from biliary limb	1.4%
Marginal ulcers and GG fistula		4%		1.4%	1-6%			2%	
Cholelithiasis	28% [#] , 12% [*]	30-52.8% [#] , 7-16% [*]	26.8% [#] , 6.8% [*]		4-10%		9.3%		
Stricture/stenosis	0.26-4%	GI:5%						GI:2%	
Malabsorption				2.5-6.6% PCM: 1 st year:3-5%; 2 nd year: 1-3.7%; beyond 2 year: 0-1%	0.5-1%				
QOL issues			WLF/regain: 50%	Steatorrhea: up to 1%	Diarrhea: 4-5%		Diarrhea: 4%		Vomiting: 2.4%
Vitamin B-12	3%	6.5%		33%					
Vitamin D3	23%			45.8%					
Folate	3%	25%		25.9%					
Iron	3%			Up to 15%					
Ferritin	14 %	23%		23%					

Table 5 (continued)

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Complication	LSG (33-36)	RYGB (36-40)	LAGB (36,41-43)	BPD (44)/BPD-DS (36,45)	MGB (46-48)	SADI-S/LDJB-SG (49)	II-SG (50,51)	SG-TB/SG-LB (52,53)	LGP & LAGBP (54,55)
Zinc									
At 2 years	18-34%	20-35%		74-91%					
At 5 years	12.5%	21-33%		45%					
Copper		9.6-18.8%		50.6%					

#, overall, *, symptomatic. PCM, protein calorie malnutrition; DS, duodenal stump; DEA, duodeno-enteral anastomosis; WLF, weight loss failure. LSG, laparoscopic sleeve gastrectomy; RYGB, Roux-en-Y gastric bypass; LAGB, Laparoscopic Adjustable Gastric Banding; BPD, Biliopancreatic Diversion; BPD-DS, Biliopancreatic Diversion with duodenal switch; MGB, mini gastric bypass; SADI-S, Single Anastomosis Duodeno-ileal Bypass with sleeve; LDJB-SG, Loop Duodenojejunal Bypass with Sleeve Gastrectomy; IT-SG, ileal Transposition with Sleeve Gastrectomy; SG-TB, sleeve gastrectomy with transit bipartition; SG-LB, sleeve gastrectomy with loop bipartition; LGP, laparoscopic gastric plication; LAGBP, laparoscopic adjustable gastric band plication.

jejunum, resulting in a combination of restriction and malabsorption.

Indications

- (I) Morbidly obese patients satisfying the criteria for bariatric surgery;
- (II) First stage or standalone procedure for super obese;
- (III) High risk patient where duration of procedure affects morbidity and mortality;
- (IV) Potential/future organ transplant candidates.

Contraindications

- (I) Barrett's esophagus (Relative contraindication);
- (II) Malignancy;
- (III) Liver cirrhosis with portal hypertension;
- (IV) Alcohol abuse.

Surgical anatomy

A gastric pouch of 20–30 mL is created by horizontal firing of 45 mm blue cartridge followed by vertical firing of blue 60 or 45 mm; dissection at Angle of His facilitates the final stapler firing to separate the gastric pouch from remnant stomach. It is very important to make sure the GCT is withdrawn before each firing. Keeping an alimentary limb of 75–150 cm and biliopancreatic limb of 50–150 cm, the gastrojejunal anastomosis performed either completely hand sewn or in combination with a linear or circular stapler. It is important to close the Petersen's space and the mesenteric gap to prevent internal herniation (Figure 2).

Surgical outcome

Weight loss

Most patients have significant weight loss in the early phase, which is sustained with further weight reduction in long term. In 2004, Buchwald *et al.* in their meta-analysis reported 61.6% (56.7–66.5%) EWL after RYGB (56), while the longest (up to 20 years) matched prospective follow-up data from Swedish Obese Subjects (SOS) study group showed mean percentage weight change of 32% , 25% and 27% at 1, 10 and 20 years, respectively from the baseline in patients of RYGB (57). The short-term outcomes showed 83% EWL at 24 and 77% EWL at 30 months. After 1 year, significance improvement in quality of life (QOL) parameters was reported in 95% of patients (58).

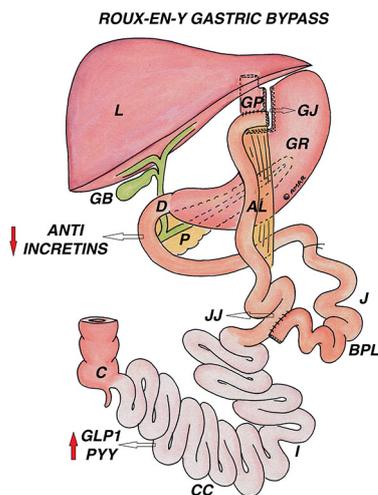


Figure 2 Roux-en-Y gastric bypass (RYGB).

Diabetes resolution/remission

Published data showed RYGB was the most effective procedure after DS in terms of diabetes remission (80% *vs.* 95%) (56,59). A 3 year comparative study (STAMPEDE Trial) in poorly controlled diabetics concluded that HbA1c <6% was achieved in 5%, 37%, and 24.5% of patients in medical treatment, RYGB, and LSG group respectively (60). More recently the 5-year data of the same study showed diabetic remission rates of 29% with gastric bypass, 23% with SG and 5% with intensive medical therapy alone (61). Diabetes re-emergence has been reported in 24–50% of the patients undergoing RYGB; contributing factors could be tapering off of hormonal effect in foregut and or hindgut, receptor down regulation and persistent stimulation of beta cells by gut incretins, leading to their exhaustion (62).

Controversial issues

Pouch and Gastrojejunostomy (GJ) size

Pouch and GJ size plays a very important role in RYGB, if pouch is really small 15–20 mL and GJ is more than 2.5 cm, then gastric emptying is faster and there is hardly any restrictive element leading to dumping syndrome. On the contrary if pouch size is much bigger and GJ is less than 2 cm then it can lead to severe retrosternal discomfort, reflux, marginal ulcer and GJ narrowing. A recent study found correlation between weight loss maintenance with GJ size but not with pouch size (63). Unfortunately, routine contrast material used to study gastric pouch volume leads to rapid transit with inadequate distension and filling.

However, authors recommend a pouch size of 30 mL and GJ diameter of 2.5 cm.

Limb length

The small bowel is elastic and distensible, thus accurate measurement is a practical difficulty. Most studies found no significant difference when the alimentary and biliopancreatic limb lengths (100 ± 50 cm) were correlated to weight loss or nutritional deficiencies, except in super obese (BMI >50) (64).

Closure of potential hernia space

Most authors recommend and agree on closure of mesenteric and Petersen's defect with non-absorbable sutures to prevent internal hernia, but conclusive evidence is still lacking (37).

Complications

These are summarized in *Table 5* (36–40).

Laparoscopic Adjustable Gastric Banding (LAGB)

Introduction

Worldwide trends showed that 24% of patients had banding in 2003, increasing to 42% in 2008, which dropped to 18% by 2011 and finally 10% by 2013 (9). Reasons for the decline could be due to suboptimal weight loss and comorbidity resolution, increasing long term complications and usage of a more effective procedure like SG. Many high volume centers have reported that they are “removing many more bands than they have placed”.

Indications

As previously mentioned.

Contraindications

- (I) GE reflux disease;
- (II) Hiatal hernia.

Surgical anatomy

The pars flaccida technique of band placement had been standardized and universally accepted. The band is ideally placed from 2 to 8 o'clock position in an oblique position

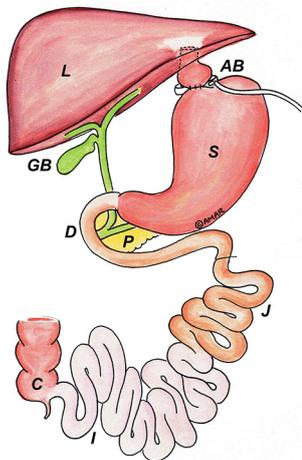
ADJUSTABLE GASTRIC BANDING

Figure 3 Laparoscopic adjustable gastric banding.

leaving a very small gastric pouch above it (Figure 3).

Surgical outcome

Weight loss

Buchwald *et al.* reported 47.5% EWL in their systematic review (56). In another review, percentage excess BMI loss (%EBMIL) at 24 and 36 months was 43.7% and 58.9% respectively (65). LAGB resulted in less weight loss for the first 2 years and although an Australian group has shown equivalent medium term (3–10 years) excess weight loss (47%) compared to RYGB (66), most studies have shown that RYGB results in better weight loss as compared to the band (67).

Diabetes resolution/remission

Buchwald *et al.* reported 47.5% resolution with LAGB, 71.6% with SG, 83.7% with RYGB, and 98.9% with Biliopancreatic Diversion (BPD) (56). Another study of 122 patients who underwent banding, 93.1% had improved fasting glucose level and 75.4% had reduction in HbA1c at the end of 1 year (65). However, long term results with sustained effects are not reported in literature.

Controversial issues

Surgical technique

The “perigastric” and the “pars-flaccida” techniques have been described in literature. Both techniques are equally effective for weight loss but former is associated with higher

slippage and erosion rates (68).

Hiatal hernia repair

A retrospective two year study reported a 1.7% reoperation rate where banding was performed with hiatal hernia repair as compared to 5.6% in standalone banding group (69). Increased pressure of the band on the upper stomach and phrenoesophageal ligament is likely to cause hiatus hernia by itself.

Fixation of band

While most surgeons advocate a suture fixation of the band anteriorly to prevent slippage, some disagree, suggesting that suturing has no advantage and increases operative time (70).

Complications

These are summarized in Table 5 (36,41–43).

BPD and Biliopancreatic Diversion with Duodenal Switch (BPD-DS)

Introduction

BPD gives the best results of weight loss, remission of T2DM and other comorbidities; but it has lost popularity due to nutritional issues following extensive bowel exclusion, causing malabsorption in the longer term. BPD-DS offers comparable results with good quality of life and lesser nutritional issues; however it requires a meticulous technique and lifelong follow-up at regular intervals to take care of impending nutritional problems.

Indications

- (I) BMI >50 kg/m²;
- (II) As a revision surgery for weight regain after other bariatric procedures.

Contraindication

Inflammatory bowel disease.

Surgical anatomy

The BPD as described by Scopinaro consists of a large gastric pouch (300–500 mL) with an antecolic alimentary

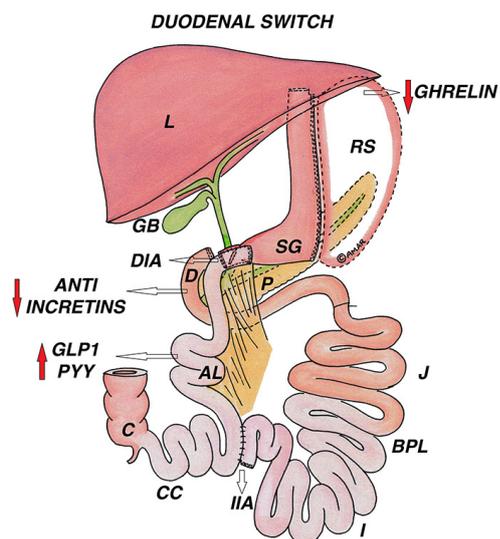


Figure 4 Biliopancreatic Diversion with duodenal switch (BPD-DS).

roux limb of 200–250 cm for the gastroileal anastomosis and a common limb of 50 cm. The original BPD has undergone several modifications; the extensive small intestine bypass is retained whereas the partial gastrectomy with gastroileal anastomosis is replaced by SG and a duodenoileal anastomosis, the duodenum being transected a few centimeters beyond the pylorus (*Figure 4*).

Surgical outcomes

Weight loss

Excellent weight loss was seen in all patients (n=360), who were super obese with a BMI >50 kg/m², at 5 years with >80% reaching a BMI <35 kg/m² (44). BPD-DS resulted in 75% EWL as compared to 54% with RYGB at 12 months in super obese patients, as reported by Sovik *et al.* in their randomized controlled trial (RCT) (71). Sustained weight loss (90% EWL) even up to 5 years is observed due to the stronger incretin response and continued malabsorptive effect of DS (72).

Diabetes resolution/remission

This is more likely to occur with BPD and BPD-DS as compared to any other bariatric procedure. Published literature reports more than 90% of T2DM resolution (72). In a group matched study where patients had mean BMI of 50 kg/m² diabetic remission was significantly better after BPD-DS as compare to RYGB (82% vs. 64%) (73).

Controversial issues

Operative mortality and morbidity

BPD and BPD-DS are judged as high risk procedures; these procedures were initially advocated for patients with BMI ≥60 kg/m², which by itself was an independent risk factor for high perioperative mortality (7.2%) (74). However, reported mortality in BPD-DS for BMI ≥60 kg/m² is 0% as reported by Fazylov *et al.* (75).

Long term nutritional issues

Protein calorie malnutrition is observed mostly during the first year with an incidence of 3–5% gradually decreasing to 1–3.7% by the 2nd year (72). There is a need to supplement high dosage of vitamins A, D, E, and K (fat soluble) with iron and vitamin-B complex.

Complications

These are summarized in *Table 5* (36,44,45).

MGB

Introduction

MGB [also referred to as omega-loop gastric bypass and one anastomosis gastric bypass (OAGB)] has been a hot topic since its inception due to controversial issues like bile reflux and risk of GE cancer. However, surgeons advocating this surgery strongly disagree regarding risk of cancer supported by the long surgical history of Billroth–II procedures, without such evidence.

Indications

All the previously mentioned indications.

Contraindications

- (I) Where gastric surveillance is mandatory;
- (II) Hepatic dysfunction.

Surgical anatomy

MGB consists of a long gastric tube along the lesser curve, starting beyond the Crow's foot with a wide antecolic gastrojejunostomy, with a biliopancreatic limb (BPL) between 150–250 cm distal to ligament of Treitz' (*Figure 5*). The authors recommend 150–200 cm of BPL to avoid

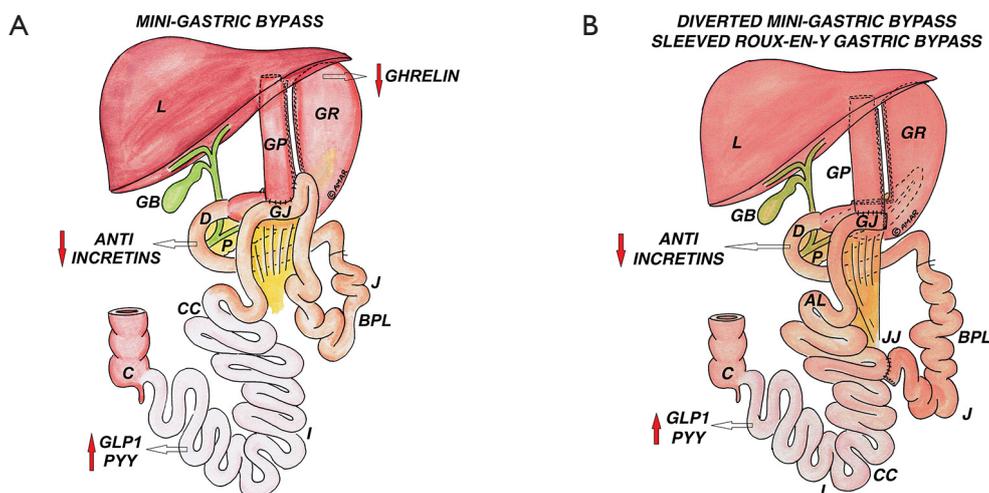


Figure 5 (A) Mini gastric bypass (MGB); (B) diverted MGB.

excessive malnutrition.

Surgical outcomes

Weight loss

%EWL after 1 year is reported to be from 55% to 91%, maintained at 85% over 6 years (46,76).

Diabetes resolution/remission

Diabetes remission was observed in 83% to 93% of patients. However long term results are still awaited (46,77).

Controversial issues

- (I) Bile reflux;
- (II) Risk of GE junction cancer;
- (III) No standardization regarding Petersen's defect closure; very few instances of internal hernias have been reported.

Complications

These are summarized in Table 5 (46-48).

Single Anastomosis Duodeno-Ileal Bypass with Sleeve (SADI-S)

Introduction

This was originally described by Sanchez-Pernaute *et al.*; it is a loop modification of DS (78). Although theoretical results have been predicted, it has to be tested against

mature bariatric operations.

Surgical anatomy

SG is performed using a 54-Fr bougie. first part of duodenum is transected 3 to 4 cm distal to pylorus. Terminal ileum is measured till 200 to 250 or even 300 cm from ileocecal junction and ileal loop is anastomosed to the divided first part of duodenum in an antecolic, end to side fashion (Figure 6).

Advantages

Endoscopic access to the sleeved stomach is maintained without any gastric remnant. Other advantages are shorter operating time, only one anastomosis and no mesenteric openings. Risk of marginal ulcers is minimal since the anastomosis is to the duodenum, rather than to stomach. Since undigested food directly enters terminal ileum, hind gut hormonal changes are comparable to those in DS.

Disadvantages

Endoscopic access to the biliary tract is lost because first part of duodenum is divided.

Surgical outcomes

Weight loss

Sanchez-Pernaute *et al.* reported 95% EWL in 19 patients

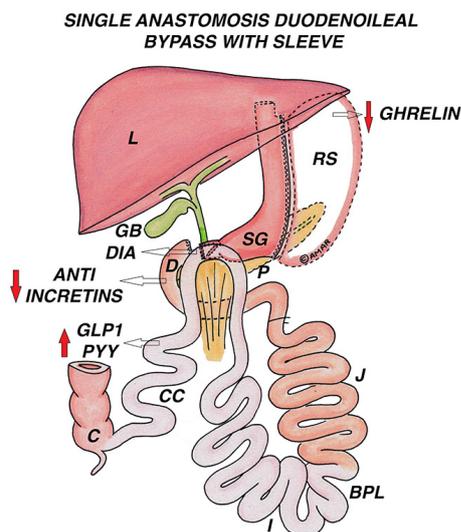


Figure 6 Single Anastomosis Duodeno-Ileal Bypass with sleeve (SADI-S).

at the end of 3 years (79). In 2015 they reported that 25 patients maintained 63% EWL at 5 years; although 6 out of the 97 obese diabetics (6.1%) failed to achieve even a 50% EWL (80). When SADI was performed as a second stage procedure after SG by the same group, they reported 72% mean EWL in 16 patients at 2 years (81).

Diabetes resolution/remission

Recently Nelson *et al.* reported 50% resolution and 33.3% improvement in T2DM between 6–12 months after SADI-S (82), while Sanchez-Pernaute *et al.* reported 88% remission (first 100 patients) (79); in the same unit when used as a second procedure after SG, remission was lower at 60% with improvement in 30% of patients (81).

As revisional surgery

One reason for the increasing interest in SADI-S is its potential usefulness in case of SG failure, which is a growing concern. With SADI-S performed in two stages, Sanchez-Pernaute *et al.* reported 72% EWL at 21 months (81), which compares favorably when SG was resleeved (43–58% EWL) or revised to BPD/DS (73–80% EWL) or RYGB (65% EWL) (49).

Controversial issues

- (I) Severe malnutrition even when the common channel is kept at 200–250 cm;

- (II) No standardization regarding closure of Petersen's space.

Complications

These are summarized in Table 5 (49).

Loop Duodenojejunal Bypass with Sleeve Gastrectomy (LDJB-SG)

Introduction

In 2013 Chih-Kun Huang introduced the LDJB-SG as a modification of SADI-S (83).

Surgical anatomy

SG is performed using a 38-Fr bougie with duodenal transection, 2–4 cm beyond the pylorus. A side to side duodenojejunal anastomosis (approx. 1.5 cm) is performed totally hand sewn with 3-0 absorbable sutures at 200–300 cm from ligament of Treitz by bringing up the jejunal loop in a iso-peristaltic and antecolic fashion (Figure 7).

Surgical outcomes

Huang *et al.* studied 22 diabetic patients (Mean duration 8 years) with mean BMI 28.4 kg/m², where all patients were on oral hypoglycemic agents (OHA) and 3 (14%) were on insulin also. 11 patients (50%) had complete remission of T2DM while 20 (91%) achieved glycemic control with HbA1c <7% without medication. Mean HbA1c dropped from 8.6% to 6.2%, fasting blood sugar (FBS) from 147 to 110 mg/dL and C-peptide from 2.4 to 1.3 ng/mL at 6 months (83). In a group matched study by the same author comparing RYGB and LDJB-SG (n=30 in each group), both procedures proved to be equally effective with respect to mean BMI, FBS and HbA1c at 1 year; both showing a significant reduction in those parameters from their preoperative levels (P<0.01). Both groups had similar comorbidity resolution, however the LDJB-SG group had better β -cell function (estimated by HOMA-II calculator) compared to the RYGB group (P=0.004); morbidity was higher in the RYGB group (P=0.08) (84).

As revisional surgery

In a case report of two T2DM patients, LDJB-SG was

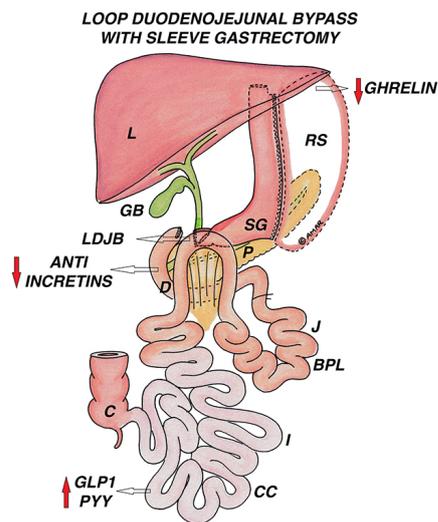


Figure 7 Loop Duodenojejunal Bypass with Sleeve Gastrectomy (LDJB-SG).

performed as revisional surgery after RYGB to overcome intractable dumping syndrome. Six months postsurgery, the Sigstad's score decreased to 2 points (85).

Controversial issues

- (I) This procedure is like a shorter DS where malabsorption is expected to be much less and efficacy is likely to be much lower;
- (II) Biliary access is lost even in LDJB-SG.

Complications

These are summarized in *Table 5* (49).

Ileal Interposition with Sleeve Gastrectomy (II-SG)

Introduction

This procedure has gained a lot of popularity as “diabetes surgery” or “metabolic surgery”, having been introduced by Aureo Depaula from Brazil in 2003 (86).

Indications

- (I) Uncontrolled diabetes inspite of optimal medical treatment;
- (II) Gradually worsening T2DM with family history of diabetes related complications;

- (III) Stimulated C-peptide >1 ng/mL.

Contraindications

- (I) T1DM, Latent autoimmune diabetes of adult (LADA) [by estimating Glutamic acid decarboxylase (GAD) antibody, islet cell antibody (ICA), and insulin auto-antibody (IAA2)];
- (II) Beta cell burn out, indicated by fasting C-peptide <0.5ng/mL and/or stimulated C-peptide <1 ng/mL.

Surgical anatomy

II with a BMI adjusted SG is performed either completely laparoscopic or hybrid (SG by laparoscopy and interposition by open approach) or robotically, where a 170 cm segment of terminal ileum is interposed into the jejunal or the duodenal area.

Jejunal ileal interposition with sleeve gastrectomy (JII-SG)

After SG, the ileal segment is interposed into the proximal jejunum, at 20–50 cm from ligament of Treitz, without any bowel exclusion (*Figure 8*).

Duodenal ileal interposition with sleeve gastrectomy (DII-SG)

After SG, the ileal segment is interposed between the divided first part of duodenum proximally, with the distal end attached to the jejunum at 50 cm from DJ flexure. This results in a bypass of the duodenum and proximal 50 cm of jejunum, eliminating the foregut anti-incretin factor (Rubino factor) (*Figure 9*).

Surgical outcomes

In a study conducted by the author, 490 patients underwent II (JII-SG 10.2%, DII-SG 89.8%) at two different centers. 63% of the patients had BMI <35 kg/m² (mean BMI 29.5 kg/m²), mean HbA1c was 9.8% and duration of T2DM 9.5 years. With a mean follow-up of 24 months (range, 10–72 months), complete remission was observed in 72% of patients and partial remission in 81.5%. These findings were supported by similar results by different authors in their respective studies (50).

Controversial issues

Complex surgical anatomy and long learning curve.

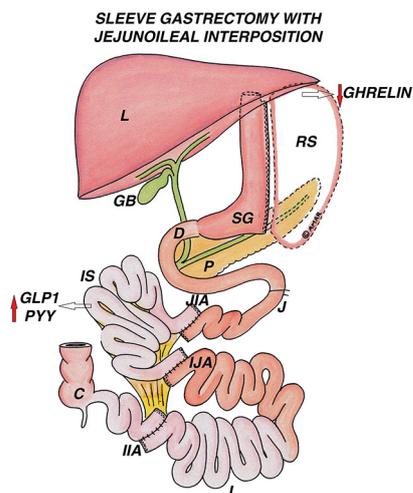


Figure 8 Jejunum ileo interposition with sleeve gastrectomy (JII-SG).

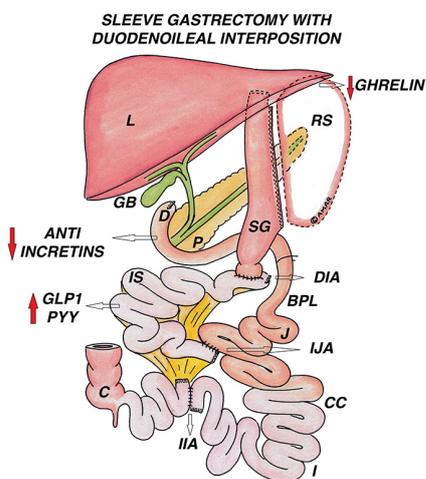


Figure 9 Duodenal ileo interposition with sleeve gastrectomy (DII-SG).

Complications

These are summarized in *Table 5* (50,51).

SG with Bipartition (Transit or Loop)

Introduction

SG with TB was first described by Santoro *et al.* (52). This was later modified by Mui from Hongkong, into SG with Loop Bipartition (SG-LB) [also known as Single Anastomosis Sleeve Ileo (SASI) Bypass as reported by Mahdy] (87).

Surgical anatomy

Sleeve gastrectomy with transit bipartition (SG-TB)

After performing a SG, the ileum is transected at 250 cm proximal to ileocaecal junction. The distal ileal end is anastomosed to the antrum in an antecolic fashion, with a stapler or completely hand sewn (anastomosis up to 3 cm is advocated to avoid excess food transit and malabsorption). This creates two potential routes for the transit of food; through the gastroileal anastomosis into distal ileum, and also through the intact duodenum; thus minimizing malnutrition and malabsorption. The proximal ileal end of the transection is anastomosed side to side at 80–130 cm proximal to the ileocaecal junction (depending on length of common channel required), to create the ileo-ileal anastomosis (*Figure 10*).

SG-LB/SASI

SG is performed keeping sufficient length of the antrum (approximately 6cm proximal to pylorus) with a loop gastroileostomy at 250 cm proximal to the ileocecal valve, using 2 layers of hand-sewn sutures/stapled anastomosis. In SASI bypass, compared to SADI-S, duodenum is not transected and the anastomosis is gastro-ileal instead of duodeno-ileal (*Figure 11*).

Surgical outcomes

Santoro *et al.* studied 1,020 obese patients (BMI 33–72 kg/m²), with a follow-up rate of 59.1% (range, 4 months to 5 years) and reported excellent weight loss (91% EBMI at 1 year; 94% at 2 years, 85% at 3 years, 78% at 4 years, and 74% at 5 years). Partial diabetes remission was seen in 86%, with a complication rate of 6%, including two deaths (0.2%) (52).

Mui *et al.* published a case report of SG-LB, with 97% EWL at 12 months follow up in a 46-year-old obese diabetic patient who achieved normo-glycemia without medication within 2 months (87). Mahdy *et al.* published results of SASI bypass in 50 patients suffering from obesity and diabetes. They have shown %EWL of 90% at one year, normo-glycemia in 100% of patients at 3 months, and resolution of hypertension (86%), hypercholesterolemia (100%) and hypertriglyceridemia (97%) (53).

Controversial issues

Marginal ulcer in transit bypass and ileal contents in stomach, in loop bipartition.

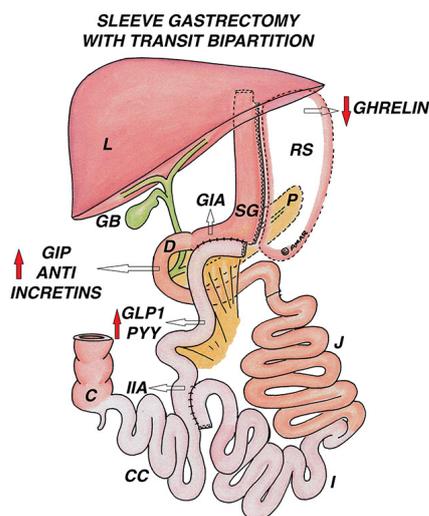


Figure 10 Sleeve gastrectomy with transit bipartition (SG-TB).

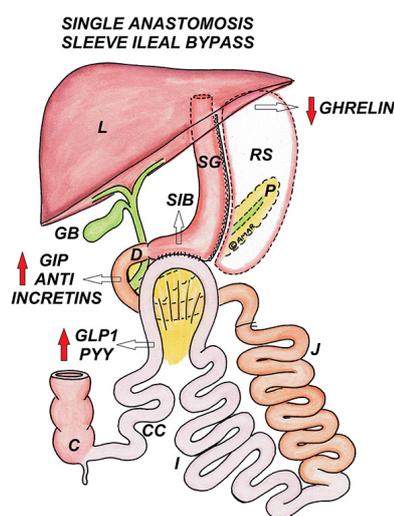


Figure 11 Sleeve gastrectomy with ileal loop bipartition.

Complications

These are summarized in *Table 5* (52,53).

Laparoscopic Gastric Plication (LGP) and Laparoscopic Adjustable Gastric Band Plication (LAGBP)

Introduction

LGP was introduced by Talebpour *et al.* from Iran with promising results in a 12-year study (88). This technique was further modified by Huang *et al.* by adding an adjustable gastric band to the plication, creating a dual restriction. Weight loss is brought about by plication and long term weight maintenance is ensured by the adjustable band. A group-matched study of patients undergoing either SG or LAGBP showed that weight loss, comorbidity resolution and complications were similar in both groups at 2 years (89).

Surgical anatomy

LGP

After devascularization of greater curvature till GE junction, the stomach is plicated from the fundus up to 3 cm proximal to the pylorus, using 2-0 non-absorbable sutures, interrupted at 2 cm intervals to invert the greater curvature, followed by a continuous sero-muscular suture to reinforce it; this prevents the herniation of gastric wall through the interrupted sutures (*Figure 12*).

LAGBP

After completing the plication, a gastric band is placed using the pars flaccida technique without gastric sutures (*Figure 13*).

Surgical outcomes

In a 12-year study of 800 cases, LGP resulted in 70% EWL at 2 years and 55% at 5 years, though 31% had weight regain (88). The %EWL in all studies of LGP is comparable to SG (around 50% in 6 months, 60–65% at 12 and 24 months) (90). In another study, SG showed a greater and statistically significant %EWL up to 18 months when compared with LAGBP, though there was no difference at 2 years (89). Multicentric international publications suggest that the efficacy of LGP and its metabolic effects on T2DM lie between AGB and SG (91).

Controversial issues

Even though staplers are not used in gastric plication, bleeding and leaks have been known to occur.

Complications

These are summarized in *Table 5* (54,55).

Revisional Bariatric surgeries

There has been a marked increase in revisional bariatric

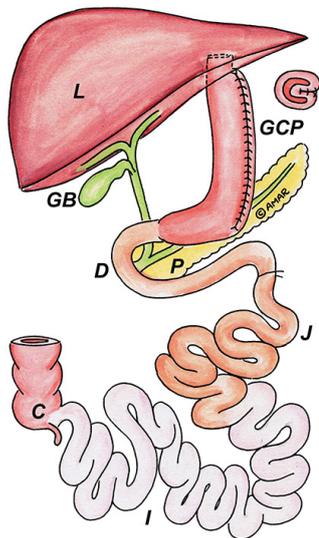
GREATER CURVATURE PLICATION

Figure 12 Laparoscopic gastric plication.

surgeries in the last few years, ranging from 5–43%, probably due to poor choice of the primary procedure with unsatisfactory weight loss or weight regain, recurrence of diabetes and chronic complications requiring intervention. However, there is no clarity regarding its indications, based on evidence.

LAGB

It is well documented that weight loss with LAGB is less than other procedures. Conversions to RYGB, SG, DS or other modifications can be done to improve results or treat complications like slippage, dilatation, migration, erosion, port/tube problems or band intolerance. Some centers report fewer complications when the conversion is done in 2 stages (definitive procedure 2–6 months after band removal). Conversion from LAGB to RYGB has been reported in 2–28.8% of cases (92). In a review of 588 patients from 15 studies evaluating conversion of LAGB to RYGB, the overall complication rate was 8.5% (anastomotic leaks –0.9%; bleeding –1.8%) with 23–74% EWL and follow-up ranging from 7–44 months (93). In conversions of LAGB to SG (286 patients from 8 studies in the same review), there was 31–60% EWL with 12.2% complication rate (staple-line leak –5.6%, probably due to scar tissue caused by the band near GE junction) (93). Small case series report better outcomes when LAGB is converted to a more malabsorptive procedure.

RYGB

Revision of RYGB may be required to deal with complications (marginal ulcer, gastro-gastric fistula, intractable dumping syndrome, and malnutrition), inadequate weight loss, weight regain, or recurrence of diabetes. Factors like pouch or stoma dilation, gastro-gastric fistula or a persistent marginal ulcer can be treated by refashioning the pouch and GJ (63). Alternately, increasing the biliopancreatic limb length or banding the gastric pouch can be used to improve results. However, the reported leak rates of such revisional procedures are very high ranging from 8.5% to 22% (94). There are few case reports of RYGB conversion to SG or LDJB-SG for intractable dumping, severe neuroglycopenia, or malnutrition (95).

Laparoscopic SG

Indication for revisional surgery after SG can be weight regain, leak (acute or chronic), stricture or cork screw deformity of sleeve, and severe GERD not responding to medical management. Different options available to treat weight regain and metabolic recidivism are conversion to MGB, SADI-S, LDJB-SG, bipartition, or ileal transposition. RYGB is a better option in case of severe GERD, chronic leak and stricture. Laparoscopic seromyotomy for stenosis at incisura has been another method in presence of severe reflux and dysphagia but is associated with high leak rate of up to 35% (96). The utilization of a roux limb to create an internal sump proximal to the stricture and to treat chronic leaks has been reported (97).

Conclusions

Although it has been conclusively documented through RCTs that bariatric surgery has a definite, long-term and significant advantage over medical management (along with lifestyle interventions) in treatment of morbid obesity, the majority of the people still shy away from surgery. Lack of sufficient support from physicians, fear of complications, few reports of mishaps, social prejudices or misunderstandings and financial considerations are usually responsible, whereby globally, only 1–2% of the eligible persons get surgery done. Rapid advances in bio-medical technology and refinement of procedures and techniques, to make surgery safer with lesser side-effects, are making these treatments more acceptable for the morbidly obese patients with or without diabetes. Many studies have shown great

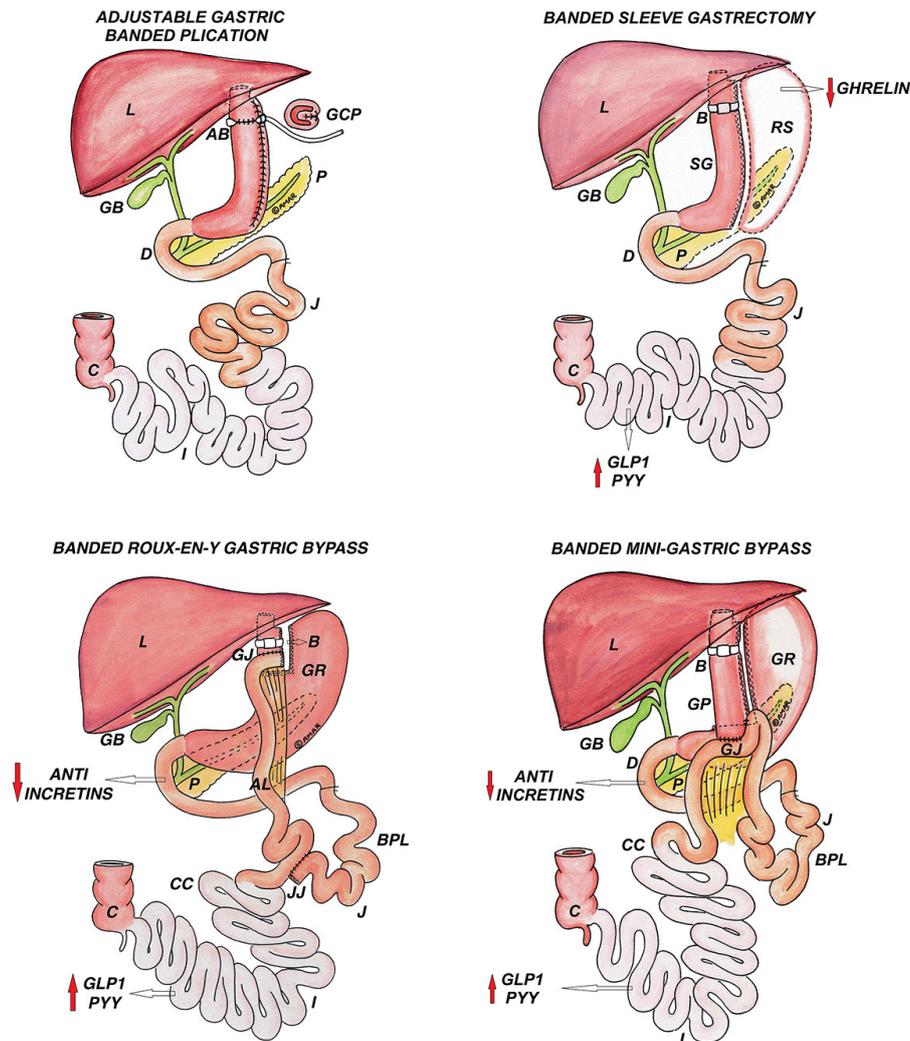


Figure 13 Banded procedures.

benefit in uncontrolled diabetics, even with lower BMIs of 30–39 kg/m².

Greater acceptance amongst patients is likely, if the non-surgical fraternity and society, are convinced of very high surgical and long-term nutritional safety and better quality of life, through clear-cut guidelines and protocols, standardisation of all procedures, individualisation for each patient to get good outcomes and better counselling and nutritional follow-up.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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