Review

The Development of the Surgical Treatment of Morbid Obesity

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Morbid obesity is defined as obesity with a body mass index ≥40, or ≥35 with secondary serious diseases. Conservative medical therapies in these individuals generally fail to sustain weight loss. Thus, surgical operations have evolved which are based on gastric restriction and/or malabsorption. Historically, the intestinal bypass operation was followed by the gastric bypass operation (in some instances combined with intestinal bypass) or by the gastric restriction operations (gastroplasty or gastric banding). Laparoscopic techniques are now being used for these operations, but require surgical expertise in both the bariatric operations and advanced laparoscopic skills. All operations may have complications, but these occur in a very small percent. Postoperative follow-up and nutritional surveillance are mandatory. The operations result in significant weight loss, and the current operations have a mean lasting weight loss of about 50 percent of excess body weight, with improvement or resolution of most obesity-associated conditions. There is evidence that even modest to moderate weight loss in these individuals has significant medical benefit.

Key teaching points:

- Morbid obesity results in progressive serious medical diseases.
- This obesity has been found to be refractory to conservative therapies.
- Effective operations which sustain significant weight loss (i.e., loss of 40% to 80% of excess weight) have developed.
- These operations depend on gastric restriction and/or intestinal bypass (malabsorption).
- The postoperative complication rates are low, and the sequelae of massive obesity reverse as the weight loss occurs.

INTRODUCTION

Obesity is the most common form of malnutrition and has been increasing over the past few decades, not only in western society but also globally [1–3]. Various treatments have been in use, with varying results. However, massive or clinically severe obesity is a major challenge, in that standard conservative treatments do not result in or sustain meaningful weight loss in these individuals [4–7]. This degree of obesity has been called "morbid obesity," which for many years has been a medical subject heading (MeSH) in the Index Medicus. Morbid obesity is associated with progressive, serious and debilitating co-morbidities [8–11]. It has generally been designated as obesity with a body mass index (BMI) ≥ 40 kg/m^2, or ≥ 35 with significant secondary diseases. Excess weight is generally determined as the weight above the *ideal weight* for longevity or survival [1,12,13] and is reported as percent of excess weight.

Progressive type II diabetes, hypertension, hyperlipidemia, accelerated atherosclerosis, debilitating arthritis of weight-bearing joints, alveolar hypoventilation, sleep apnea syndrome, gastroesophageal reflux disease, infertility and urinary stress incontinence in females, certain cancers and sudden death are among the major co-morbidities [14–19] (Table 1). Inability to take part in activities of daily living, immobility, psychosocial and economic problems, and disability are accompaniments. This extreme obesity rarely responds to conservative regimens,

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Table 1. Common sequelae of massive obesity [13]

Hypertension	Pulmonary embolism
Dyslipidemia	Reflux esophagitis
Accelerated atherosclerosis and angina pectoris	Hernias
Cardiomegaly	Urinary stress incontinence (women)
Impaired glucose tolerance	Hirsutism in women
Debilitating arthritis of back and weight-bearing joints	Amenorrhea
Immobility	Infertility problems in women
Fatigue, dyspnea, diaphoresis	Endometrial hyperplasia and carcinoma of endometrium
Alveolar hypoventilation and somnolence	Carcinoma of breast
Obstructive sleep apnea	Carcinoma of prostate and colon in men
Hepatic steatosis	Foul intertrigenous dermatitis
Cholelithiasis	Accident proneness
Venous stasis leg ulcers	Psychosocial and economic problems
Deep vein thrombosis	

e.g. diets, psychotherapy, anorexiant medications, and the like, but has been successfully managed with surgery. This field is termed *bariatric surgery* (*bari:* old Hebrew—fat) [20] and is aimed at achieving sustained weight loss and reversal of the co-morbidities. An overview of the bariatric operations follows.

BARIATRIC OPERATIONS

Intestinal Bypass

In the 1950s, it was noted that individuals who had the short-bowel syndrome lost weight. This led to performance of the jejuno-colic bypass [21]. Unfortunately, the intestinal lengths used resulted in persisting fluid and electrolyte imbalance and liver dysfunction.

This led in the 1960s and early 1970s to the development of the jejuno-ileal (JI) bypass. The JI bypass was performed end-to-side [22] or end-to-end [23], using lengths which had been developed to permit survival with the controlled short-bowel syndrome produced (Fig. 1A and B). Initial postoperative fluid and electrolyte imbalance frequently required replacement of potassium, magnesium and/or calcium. Occasionally, oxalate renal stones, migratory polyarthralgia, abdominal bloating and major liver dysfunction ensued [21]. These were controllable, but required very close surveillance, which often tied down the surgeon. Weight loss in many series has been very satisfactory (mean loss of 60% of excess body weight). There are many patients who could not have survived until today without the weight loss following a JI bypass [24].

While the JI bypass has been largely abandoned, this operation has been continued by a few surgeons, with modifications, such as draining the bypassed jejuno-ileum into the upper stomach (ileo-gastrostomy) [25] or draining the gallbladder into the bypassed jejunal stump (bilio-intestinal bypass) [26].

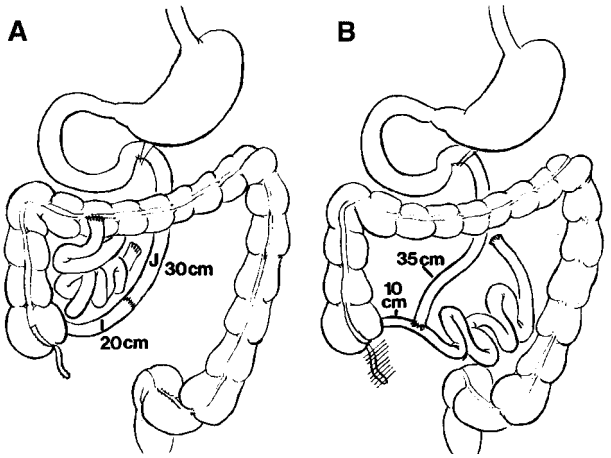

Fig. 1. Jejuno-ileal bypass. **A.** End-to-end, with the bypassed small bowel anastomosed to colon. **B.** End-to-side, with the proximal jejunum anastomosed to the distal ileum. The malabsorption results in weight loss. The appendix is removed in all JI bypasses.

Gastric Bypass

In the 1960s, Mason noted that patients after a high gastric resection frequently developed sustained weight loss. Accordingly, he initiated the gastric bypass using a jejunal loop [27] (Fig. 2A). In this procedure, the jejunal loop was brought up to the proximal stomach often under tension which increased the

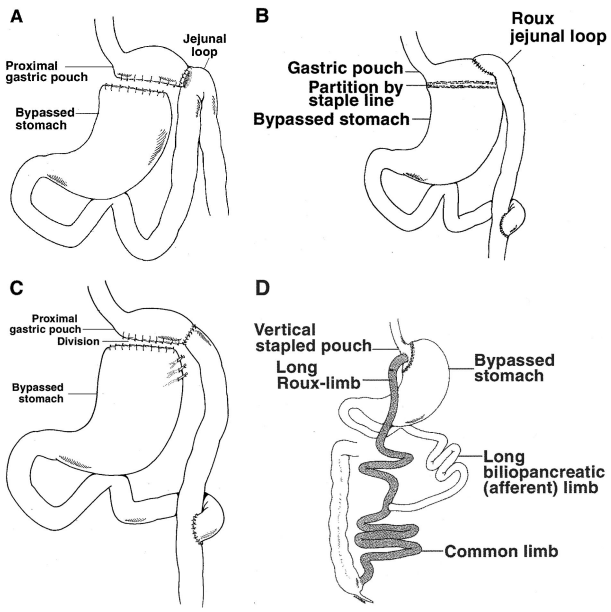

Fig. 2. Gastric bypasses, with tiny proximal gastric pouch restricting intake and jejunal loop providing some malabsorption. **A.** Loop gastric bypass of Mason. **B.** Roux-en-Y configuration, with stomach partitioned by staple-lines. **C.** Roux-en-Y configuration, with divided stomach. **D.** Distal Roux-en-Y gastric bypass: stapled gastric pouch with Roux-limb anastomosed to the lesser curvature (Torres [29]); the shaded area represents Roux (alimentary) limb and common (major digestive) limb.

likelihood of an anastomotic leak, which would be catastrophic because of egress of copious caustic gastro-duodeno-bilio-pancreatic secretions.

Thus, the configuration was changed to a Roux-en-Y (which decreased the stretch on the mesentery and eliminated bile reflux) [28]. Some workers partitioned the stomach by application of a linear stapler [29] (Fig. 2B), but staple-line disruption was a problem, and would defeat the weight loss as well as occasionally result in the development of an ulcer on the jejunal side of the anastomosis (marginal ulcer) [30]. Thus, many surgeons divide the stomach, leaving an upper tiny pouch and the large lower gastric segment (Fig. 2C). Patients generally maintain a long-term loss of 50% of excess body weight. In order to increase the rapidity of weight loss, the biliopancreatic or Roux limbs were moved more distally [31] (Fig. 2D), but with the far distal Roux-en-Y configuration, excess protein malabsorption and hypoalbuminemia may be a complication. These operations require nutritional surveillance, and supplements of multi-vitamins, vitamin B_{12}, folic acid, iron, calcium (e.g. Turns or Caltrate) and occasionally other nutrients [32]. Such supplements are widely available for these patients. Among the early postoperative complications in these patients are thromboembolism, pulmonary atelectasis and cardiac events, but serious late complications are uncommon.

Gastroplasty

In the mid-1970s, in an effort to simplify gastric restriction, Mason divided the stomach transversely towards the greater curvature where he left a small channel; however, this outlet subsequently enlarged. This led to experimentation with horizontal gastroplasties [33, 34] (Fig. 3A and B); unfortunately, the upper gastric pouch and the outlet tended to enlarge, leading to regain of weight. In response, Mason partitioned the stomach vertically, because the thicker muscle along the lesser curvature may be more resistant to dilatation (vertical gastroplasty); in addition, the outlet was banded by a mesh strip or a silastic ring to prevent enlargement [35, 36] (Fig. 4A and B). The vertical banded gastroplasty has been widely performed and has been associated generally with satisfactory weight loss, but less than following the gastric bypass.

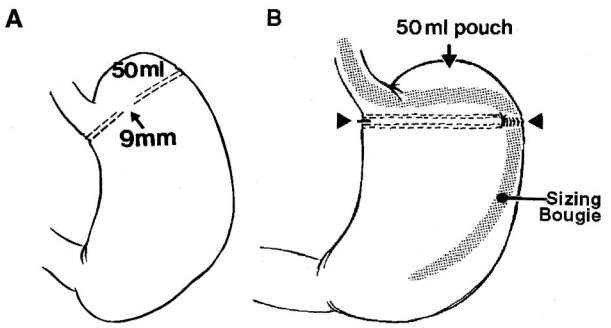

Fig. 3. Horizontal gastroplasties with small proximal gastric pouches. **A.** Central staples removed, and stapled partition constructed (Carey [33]). **B.** Stapled partition, with staples on greater curvature removed (arrow heads) and outlet reinforced by a circumferential suture (Gomez [34]).

Gastric Balloons

In the 1980s, intragastric balloons were developed [37]. These were inserted by gastroenterologists endoscopically and inflated with air, in a vast number of obese individuals. The weight loss was modest and temporary and, indeed, appeared to be similar to controls in sham studies [38]. Pressure ulceration in the stomach was occasionally reported. However, the major problem was balloon breakage, which would release the air so that the balloon could migrate through the pylorus into the intestine, where it could cause intestinal obstruction. A new version of the balloon consisting of a smooth silicone sphere, filled with saline to provide a heavy sensation, is being trialed in Europe; this balloon also has some methylene blue dye injected into it, so that balloon breakage will be identified by discoloration of the urine [39].

Biliopancreatic Diversion

In the late 1970s, Scopinaro in Genoa began developing the biliopancreatic diversion (BPD). Leaving a biliopancreatic limb (BPL) anastomosed to an alimentary limb (AL), with a comparatively short distal common limb (CL), this operation required a partial gastrectomy to avoid marginal ulceration [40] (Fig. 5). If the gastric remnant in the BPD was too small for adequate oral intake, hypoalbuminemia and nutritional sequelae could occur, unless a longer common limb were left. The weight loss initially is related to the restriction of food intake from the decreased size of the available gastric pouch (which later enlarges), but this weight loss is maintained by a tolerable degree of malabsorption of starches and fats in the common limb. The BPD provides the greatest loss of excess weight (80% excess weight loss) of any of the bariatric operations, but requires utmost surgical expertise. In addition, the BPD demands close long-term follow-up, since nutritional deficiencies may develop.

Duodenal Switch

A modification of the BPD in wide use is the "duodenal switch" operation [41, 42] (Fig. 6). This is performed by resection of the greater curvature of the stomach (which initially produces some gastric restriction), leaving the entire lesser curvature and pylorus in continuity. By leaving the pylorus intact, dumping syndrome and marginal ulceration are prevented. The alimentary limb (AL) is anastomosed to the divided proximal duodenum (proximal to common bile duct). The biliopancreatic limb (BPL) is anastomosed to the side of the alimentary limb 75–100 cm proximal to the ileocecal valve, leaving this common limb (CL) for absorption.

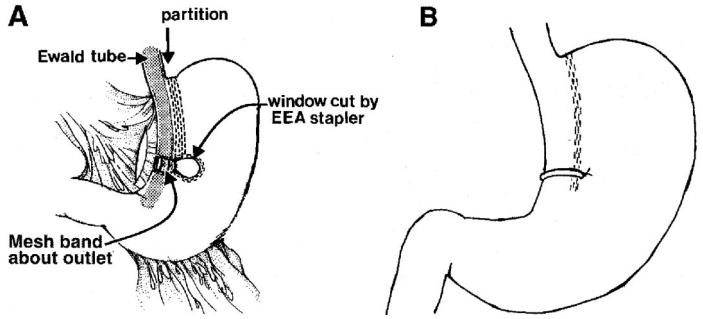

Fig. 4. Vertical banded gastroplasty. **A.** "Window" enables introduction of a stapler for partition. Mesh band prevents enlargement of outlet [35]. **B.** Special stapler permits partition without a "window". Silastic ring prevents enlargement of the outlet [36].

The BPDs require a cholecystectomy, as bile stasis and rapid weight loss are greatest with this operation, although gallstone formation also may follow the other weight loss operations but to a lesser extent [43].

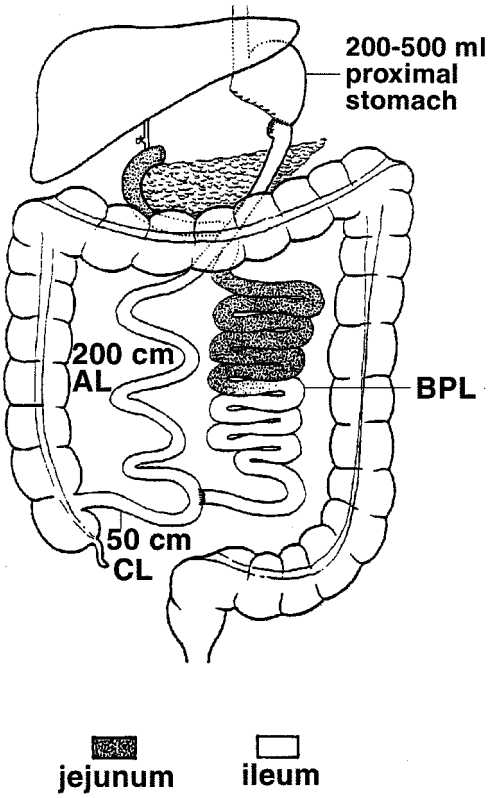

Fig. 5. Biliopancreatic diversion (Scopinaro [40]). A distal gastrectomy is performed. Small bowel is divided 250 cm proximal to ileocecal valve, and is anastomosed to the stomach remnant. The biliopancreatic limb (BPL) is anastomosed to the side of the distal limb 50 cm proximal to the ileocecal valve, to form a 200-cm alimentary limb (AL) and a 50-cm common limb (CL) where the major digestion occurs. The proximal gastric pouch initially restricts intake, which is maintained by the reduced absorptive area. Cholecystectomy is done to prevent gallstones from bile stasis and rapid weight loss.

Gastric Banding

In the 1970s, gastric banding (GB) was initiated to achieve gastric partitioning without stapling (Fig. 7). Problems with this procedure included occasional slippage or migration of the band or the development of an excessively large upper gastric pouch with vomiting. On the other hand, the outlet from the upper pouch was occasionally left too large for adequate gastric restriction and weight loss. Some surgeons continued to perform GB over the years, with considerable expertise [44].

In the late 1980s, the *adjustable* GB was developed, with a hollow band connected to a tube attached to a reservoir in the upper abdomen on the anterior rectus sheath (Fig. 7). This reservoir permits adjustment of the gastric restriction by injection or withdrawal of saline (or a radiopaque liquid) from the reservoir [45, 46]. Very high insertion of the gastric band which is anchored anteriorly by gastro-gastric sutures has decreased postoperative band and pouch problems.

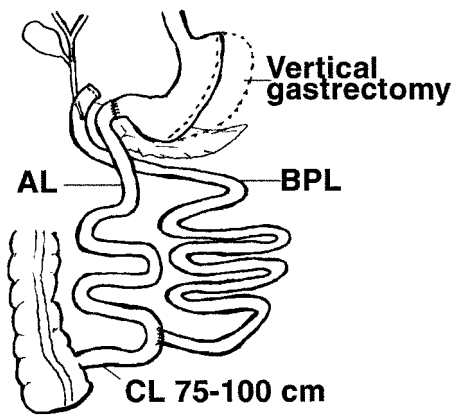

Fig. 6. BPD with duodenal switch. The greater curvature portion of stomach is resected to provide initial gastric reservoir reduction. Ileum is divided, and the alimentary limb (AL) is anastomosed to the divided proximal duodenum. The biliopancreatic limb (BPL) is anastomosed to the side of the AL 75–100 cm proximal to the ileocecal valve, forming the distal common limb (CL) [41, 42].

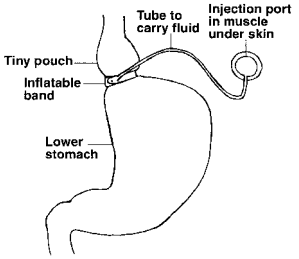

Fig. 7. Adjustable gastric band. A reservoir under the skin communicates with hollow band, and injection or withdrawal of saline can tighten or loosen the band.

Laparoscopic Technique

In the past decade, laparoscopic (minimally invasive) surgery has become a prominent approach for bariatric operations. A pneumoperitoneum is produced by insufflation with CO_2, and the operation is viewed via a laparoscope connected to a TV-screen and performed through trocar sites. The development of specialized instruments, which obviate the need for the traditional abdominal incision and the placing of the surgeon's hands on the organs, has advanced laparoscopic surgery. This technique enables rapid mobilization of the patient postoperatively, early hospital discharge, rapid healing, and early return to work. The gastric banding procedure particularly lends itself to laparoscopic techniques [45, 46], but every bariatric operation can be performed laparoscopically by surgeons who are thoroughly experienced in *both* open bariatric operations and laparoscopic technique [47–49]. All these operations have a learning curve.

NUTRITIONAL REQUIREMENTS FOLLOWING BARIATRIC OPERATIONS

Although significant nutritional complications are uncommon following most bariatric operations (if patients are carefully followed), they still may occur. Dehydration, protein malnutrition, and vitamin and mineral deficiencies must be considered. These deficiencies are usually the result of dramatically reduced nutritional intake, altered diet and/or decreased efficiency of absorption.

Dehydration

Mild dehydration is commonly seen in the early postoperative phase for all of the bariatric operations and is mainly due to decreased intake. For the gastric restrictive procedures, patients have difficulty drinking the necessary fluid volumes as they adapt to very small gastric capacities. With the malabsorptive procedures, the frequent watery stools are a source of significant fluid loss. With any of these operations, vomiting or diarrhea may exacerbate fluid losses. Standard fluid recommendations are impossible, given the heterogeneity of the patients. In addition, there are no mathematical equations that accurately estimate fluid needs in the obese. Patients are instructed to use thirst and urine concentration as a guide for fluid intake.

Protein

Protein malnutrition is an uncommon occurrence with the gastric restrictive procedures including the proximal gastric bypass. Patients are instructed to follow a high protein diet to include approximately 60–80 gm of protein daily. If achieving this level of protein intake is difficult, as many patients are meat intolerant, protein supplements may also be used. For the malabsorptive operations such as the distal gastric bypass and the biliopancreatic diversion, protein may also be lost in the stool. Higher intake may be necessary and should be guided by serum protein levels as well as diet and bowel habit activity.

Vitamins and Minerals

Since the pure gastric restrictive operations, such as gastric banding and the vertical banded gastroplasty, do not alter nutrient movement through the upper gastrointestinal tract, vitamin and mineral deficiencies are uncommon. However, they still may occur, secondary to the changes in diet both in quantity and composition. For example, many of these patients do not tolerate red meat (unless minced or chewed very well) and avoid it. They are therefore at greater risk of iron deficiency.

Proximal gastric bypass patients are commonly at risk for deficiencies of iron, folate, calcium, vitamin B_{12} and vitamin D. While dietary changes are a component of this problem, the bypass of the majority of the stomach, the duodenum and proximal jejunum by the nutrient stream is also a factor. Iron, vitamin B_{12} and calcium absorption are in part dependent upon these regions. However, most patients can be maintained with diet and the supplementation of a daily complete vitamin and calcium. For all these patients, serum levels should be monitored twice yearly. Recommendations generally suggest that patients take 325 mg of an iron compound (usually gluconate, more in menstruating women and in patients who are consuming very little meat), 500–600 mcg of B_{12}, 1 mg of folate, and 500–1000 mg of calcium daily. Patients with significant vomiting, poor food intake, or women of childbearing age may require additional vitamin and iron supplementation.

In contrast, the malabsorptive operations place a greater percentage of patients at greater risk for deficiencies which include the above vitamins and calcium, but also may include the fat-soluble vitamins, electrolytes such as sodium, potassium, chloride, phosphorus, magnesium, and possibly the trace element zinc. Serum levels should be aggressively followed and supplementation judiciously done.

DISCUSSION

As long as the weight loss following the surgery is maintained, the diseases which had been associated with the massive

Table 2. Comorbidity outcomes following bariatric surgery

Comorbidity	% Improved or Resolved
Diabetes	100%
Coronary artery disease	100%
Hypercholesterolemia	96%
Gastroesophageal reflux disease	96%
Sleep apnea	93%
Hypertension	88%
Osteoarthritis	88%
Hypertriglyceridemia	86%
Depression	55%

Adapted from Schauer *et al.* [53].

obesity are reversed. There is some evidence that sustained modest weight loss in these individuals provides very significant alleviation of the co-morbidities [50–52]. Few other interventions in medicine have been shown to affect such a wide range of comorbidities positively (Table 2) [53]. Lifelong postoperative follow-up is necessary, at decreasing intervals, and social and psychological support are frequently necessary. Plastic surgery for the abdominal overhang (with its underlying skin irritation) and for other redundant skin is frequently helpful after the weight loss [54].

Because the operations for morbid obesity have undergone development and change over the past 50 years, some medical practitioners have stated that there may not be a satisfactory operation for morbid obesity. Improvements in the operations for morbid obesity, the occasionally difficult patients, and a lack of sympathy by society for massively obese individuals [55], have fostered this opinion. However, it should be noted that in all areas of General Surgery over the past 50 years, there have been changes, development and progress [56]. If we consider the operations for duodenal ulcer, sliding hiatal hernia with gastroesophageal reflux, bleeding esophageal varices, cancer of the breast, inguinal hernia, gallstone disease, rectal prolapse, and even hemorrhoidectomy, as well as changing methods in surgical nutrition, transplantation, and the like, we realize that all areas of General Surgery are continually in metamorphosis, development and generally improvement. Bariatric surgery likewise has advanced.

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