Evolution of Bariatric Surgery: A Historical Perspective

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OBJECTIVE. Older legacy bariatric surgical procedures, including jejunocolic bypass, jejunoileal bypass, vertical banded gastroplasty, and biliopancreatic diversion, are no longer performed. Biliopancreatic diversion with duodenal switch is still performed in select centers. Although the legacy procedures are no longer performed, there are still patients who have undergone these surgeries in the past who are currently either under continuous surveillance or are being evaluated for surgical conversion or revision because of complications or weight regain. The purpose of this article is to describe the evolutionary development of various bariatric surgical techniques and the associated surgical anatomy. Because these procedures are no longer performed, only limited imaging of legacy bariatric surgeries is available for radiologic demonstration.

CONCLUSION. Although earlier bariatric surgical techniques are no longer favored, there are still patients who underwent these procedures who require imaging evaluation for clinical follow-up or surgical revision. Understanding the radiologic-surgical anatomy of these older bariatric procedures can help in the prompt and appropriate management of these patients.

Keywords: bariatric, biliopancreatic diversion, gastric bypass, gastrojejunostomy, gastroplasty, jejunocolic

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The obesity health crisis and its known associated comorbidities are only a few decades old. For many centuries, as a consequence of chronic scarcity of food, obesity and corpulence were associated with affluence, power, health, and prosperity. It was after the technologic advances starting in the 18th century that food became more affordable and more readily available. The initial results of these advances were improved public health and longevity. Late in the 19th century, obesity became recognized as an aesthetic issue, and in the 20th century it was recognized as a health problem [1].

Jaw wiring was the earliest attempt to alleviate obesity on the basis of the assumption that enforced reduction in food intake would result in sustained weight loss [2]. This procedure proved to be unsuccessful because it still allowed the patient to consume high-calorie liquids, which eventually resulted in weight regain. In addition, patients had difficulty maintaining oral hygiene, resulting in dental infections. Emesis and aspiration with resulting respiratory tract infection were also concerns [3]. Jaw wiring was therefore discontinued, but an important concept in bariatric management was recognized: the need for a procedure with the ability to provide permanent results and, hence, the evolution of surgical management of obesity.

Surgical Techniques

The initial era of bariatric surgery began with the observation that a surgically shortened small intestine and secondary malabsorption resulted in sustained weight loss. In 1954, Kremen et al. [4] reported that resection of a controlled length of small intestine in dogs resulted in impaired fat absorption and consequent weight loss. They also noted that those patients who lost a portion of their small intestine for various reasons lost weight despite increased caloric intake. These observations cultivated the beginning of bariatric surgery as we know it today.

Because the majority of nutrient absorption occurs in the small intestine, it was the first region of the gastrointestinal tract considered for surgical revision to produce weight loss. The small intestine normally measures approximately 550 cm in length. A significant decrease in the functional absorptive length of small intestine can result in impaired absorption of nutrients and "dumping syndrome" associated with certain food intake. Dumping syndrome can result in diarrhea, nausea, and bloating. The additional re-

TABLE 1: Classification of Legacy Bariatric Surgical Procedures According to Their Gastrointestinal Effects

Gastrointestinal Effect	Procedures
Predominantly malabsorptive	Jejunocolic bypass and jejunoileal bypass
Predominantly restrictive	Vertical banded gastroplasty and horizontal gastroplasty
Mixed malabsorptive and restrictive	Biliopancreatic diversion and biliopancreatic diversion with duodenal switch

sultant negative physiologic feedback mechanism from dumping syndrome can further deter ingestion of high-calorie foods [5].

Jejunocolic Bypass

In 1963, Payne et al. [6] performed the first surgical procedure for weight loss in obese patients. The jejunocolic bypass, a purely malabsorptive procedure, consisted of dividing the small intestine 35–50 cm distal to the ligament of Treitz. The proximal segment was then anastomosed to the proximal transverse colon in an end-to-side fashion. The distal end was simply closed blindly, leaving a long blind loop of small intestine. This procedure was later modified to include anastomosis of jejunum to proximal ascending colon to help decrease the degree of diarrhea (Fig. 1).

After the surgery, the majority of weight loss occurred in the first postoperative year. In all subjects, decreased absorption of fats and resultant decreased serum cholesterol and lipoproteins was noted. However, fatty stools, significant diarrhea, and anal complications were observed in nearly all patients. These findings were seen for many years after surgery, even when the patients' weight had stabilized [7].

Poor absorption of vitamins B12, A, and D and low levels of such minerals as magnesium, potassium, and calcium also occurred, which required continuous replacement [8]. Other complications included dehydration, electrolyte imbalance, hypoprothrombinemia, postural hypotension, tetany, joint symptoms, anemia, cholelithiasis, nephrolithiasis, fatty infiltration of the liver, hepatic cirrhosis, and hepatic failure [9]. Because of severe complications, jejunocolic bypass was abandoned, and many were converted to jejunoileal bypass [9].

Jejunoileal Bypass

In 1969, Payne and DeWind [10] recommended jejunoileostomy for surgical treatment of obesity. This procedure involved dividing the small intestine 35 cm distal to the ligament of Treitz and anastomosing the proximal segment of jejunum to the terminal ileum, 10 cm proximal to the ileocecal valve in an end-to-side fashion (Figs. 2 and 3).

In 1976, Scott Jr. et al. [11] recommended an end-to-end anastomosis of the jejunum to ileum, where the bypassed long segment of the small intestine was anastomosed into the transverse or sigmoid colon (Fig. 4). Investigators claimed better weight loss and maintenance because of lack of reflux of nutrients into the bypassed small intestine, which was present in the end-to-side jejunoileostomy [12] (Fig. 5).

Although the long-term weight loss differed with both variants of the jejunoileal bypass procedures, the majority of patients lost a significant amount of weight within the first postoperative year [13]. Pi-Sunyer [12] reported that the degree of the patient's obesity determined how closely the desirable weight would be achieved; the heavier the patient, the earlier a weight plateau would occur. Jejunoileal bypass, however, was associated with several significant complications as well.

Anaerobic bacterial overgrowth in the long excluded blind loop, termed "bypass enteritis," resulted in abdominal distention and lactose intolerance and contributed to the foul-smelling flatus and stool commonly observed in these patients. Absorption of the bacterial toxins resulted in polyarthralgia and hepatic failure. Continuous diarrhea also resulted in anal excoriation and hemorrhoids [13]. In addition to short gut syndrome, alterations to luminal absorption of fatty acids, calcium, and oxalate led to increased incidence of nephrolithiasis and renal failure. Loss of potassium, calcium, and magnesium, as well as vitamin and protein deficiency, resulted in secondary neuropathy, bone demineralization, myalgia, peripheral weakness, and edema [14]. As adaptation to the short gut syndrome progressed, the capacity to absorb carbohydrates increased, which resulted in weight regain despite the continuous protein malnutrition and malabsorption of vitamins and minerals [5].

The overall mortality rate for jejunoileal bypass was reported at approximately 4% in within the first two postoperative years and was usually related to liver failure [11]. Jejunoileal bypass has long been abandoned, and the majority of patients with this procedure have undergone reversal or revision to another bariatric procedure. There are still a small number of patients with the original jejunoileal bypass remaining, who require close clinical observation and routine follow-up of liver function as well as liver biopsies because of the increased risk of hepatic failure and cirrhosis [15].

Biliopancreatic Diversion

The experience with jejunoileal bypass led investigators to consider pairing a malabsorptive and a restrictive process to obtain maximum sustainable weight loss. The restrictive process would result in food limitation and early satiety, whereas the malabsorptive process would result in decreased nutritional absorption (Table 1).

The earliest combined bariatric procedure was the biliopancreatic diversion first reported in 1979 by Scopinaro et al. [16]. This was a modification of the jejunoileal bypass and consisted of a 200- to 250-mL horizontal gastric pouch associated with a distal gastrectomy and closure of the duodenal stump, as well as a gastroenterostomy with a 250-cm Roux limb. The biliopancreatic limb was anastomosed to the Roux limb 50 cm proximal to the ileocecal valve [5] (Fig. 6). This procedure is currently more popular outside the United States and can result in 70% long-term weight loss in more than 90% of patients [17].

Biliopancreatic diversion significantly eliminates bypass enteritis of jejunoileal bypass and the related hepatic failure. Also, the increased bowel length decreases the incidence of frequent diarrhea, renal calculi, marginal ulcers, protein malnutrition, and vitamin and electrolyte deficiencies. However, there are frequent voluminous and malodorous stools and flatus associated with this operation. Increased risk of deficiency of calcium and fat-soluble vitamins and protein requires lifelong replacement therapy. Patients can also suffer from postgastrectomy syndrome, which includes marginal ulcers and dumping [13].

Biliopancreatic Diversion With Duodenal Switch

The high incidence of postgastrectomy syndrome resulted in modification of biliopancreatic diversion with the addition of a pylorus-sparing procedure first described by Marceau in 1993 [18]. In this procedure, the greater curvature of the stomach is resected, leaving a tubelike gastric remnant while preserving the pylorus. The enteric limb (250-cm Roux limb) is anastomosed to the postpyloric duodenum. A long duodenobiliopancreatic limb is anastomosed to the Roux limb 50 cm proximal to the ileocecal valve [5] (Figs. 7 and 8).

Biliopancreatic diversion with duodenal switch is an effective surgery for weight loss, but because of its associated complications, it is reserved for superobese patients, especially those with a body mass index greater than 55. It can also be performed as a revision for other failed bariatric procedures [18]. Biliopancreatic diversion with duodenal switch allows patients to lose weight without significantly altering their eating habits, resulting in greater long-term weight loss and less weight regain [19]. Investigators have shown that a longer alimentary limb and biliary limb with a shorter common channel in superobese patients can result in greater weight loss over a 2-year postoperative period. This effect is due to decreased absorption of nutrients in the common channel, which receives food mixed with gastric, biliary, and pancreatic fluids from both alimentary and biliary limbs [20].

Although the incidence of postgastrectomy syndrome decreased with biliopancreatic diversion with duodenal switch, other associated complications are similar to those patients with biliopancreatic diversion and include calcium, iron, magnesium, vitamin, and protein deficiency, as well as malodorous stools and flatus [5]. The risk of anatomic complications related to the operative procedure is higher because of multiple anastomoses and includes bowel obstruction, ventral and internal hernia, anastomotic leak, fistulas, and abscess. Bowel obstruction is the most common complication, with two thirds of these cases involving the gastric pouch and one third of cases involving the distal anastomotic sites, most commonly the biliopancreatic limb [19].

Biliopancreatic diversion with duodenal switch is performed via laparotomy as well as laparoscopically. The first robotically assisted biliopancreatic diversion with duodenal switch was performed in 2000 by a totally intracorporeal approach. The operative mortality for biliopancreatic diversion with duodenal switch is approximately 1%. This rate is slightly higher (2.5%) for the laparoscopically performed biliopancreatic diversion with duodenal switch. This mortality rate may decrease as the surgeon gains expertise with the technical aspects of this procedure and overcomes the associated learning curve [18].

Gastric Bypass With Loop Gastrojejunostomy

In 1967, Mason noted that patients with partial gastrectomy were able to lose weight and maintain the weight loss [13]. On the basis of this observation, he developed a simple gastric bypass procedure by surgically isolating a portion of the stomach along with a retrocolic loop gastrojejunostomy. Initially, this was performed in an undivided fashion whereby noncutting staplers were used. This produced division of the two components of the stomach with a staple line without physical separation [13] (Fig. 9). A small pouch was therefore produced, which permanently restricted food intake and allowed more sustained weight loss of up to 50% of excess body weight; however, several associated complications were also noticed.

The complications included dumping syndrome, especially with ingestion of sweets and fats, breakdown of suture or staple lines, marginal ulcers, bile reflux, postoperative leaks, vitamin and mineral deficiency, and protein deficiency. In 1977, Alden [21] modified this procedure by cross-stapling the stomach and switching to an antecolic gastrojejunostomy. At the same time, Griffen et al. [22] described a Roux limb modification of this gastric bypass. Since then, several variations of this procedure have been attempted, which eventually led to the current gastroplasty techniques [5].

Horizontal and Vertical Gastroplasty

To simplify gastric restriction surgeries, in the 1970s, Mason et al. [23] developed a horizontal gastroplasty technique in which he stapled the stomach transversely toward the greater curvature, leaving a small orifice of communication between the two gastric channels (Fig. 9). This procedure was later modified by several surgeons to various configurations, including a horizontal gastroplasty with loop jejunostomy and horizontal gastroplasty with Roux-en-Y bypass, in attempts to prevent suture breakdown, dilation of the upper pouch and the outlet, and the resultant weight regain [13] (Figs. 10 and 11).

In 1980, Mason [24] and Laws [25] developed the vertical banded gastroplasty. In this technique, the stomach was vertically stapled, but not divided, creating a small 30-cm^3 gastric pouch reinforced by thicker muscles of the lesser curvature. A small outlet from this pouch was created, which was reinforced with a mesh strip or a silastic ring. This procedure was preferred for patients with obesity-related medical complications, such as hypertension and cardiac disease [26] (Figs. 12 and 13).

Because of the significant food restriction and early satiety, excess weight loss was reported at a rate of 50% in 50% of patients. However, patients would learn to modify their food intake by consuming high-calorie liquids with resultant weight regain. Breakdown of the vertical staple line occurred as well, allowing recanalization of the proximal stomach to the restricted portion (Fig. 14). As a result, patients were able to resume nearly normal amounts of food without restriction. Other complications included bezoar formation, vomiting, outlet obstruction and stenosis, staple line dehiscence, perforations and postsurgical leaks, and gastroesophageal reflux and megaesophagus [5] (Fig. 15).

Vertical gastroplasty has not been performed in the United States since the mid-1990s. Patients with the original vertical gastroplasty are now frequently revised using other bariatric procedures.

Imaging Evaluation

In the earlier days of surgical bariatric management, postoperative imaging evaluation was not consistently performed. Some surgeons would not image unless the patient exhibited clinical signs of obstruction or anastomotic leak, whereas others would do so routinely. This practice variation still exists today.

Fluoroscopic examinations of the gastric pouch and small intestine allowed assessment of leaks at suture sites, gastric emptying, and gastric peristalsis. Small-intestine transit time was usually short in this patient group, approximately 15–30 minutes [27]. CT was performed to evaluate other anatomic complications, such as leaks, abscesses, and hernias.

Conclusion

Surgical management of obesity has evolved over the past five decades and now is a popular treatment method for morbidly obese patients.

TABLE 2: Conversion of Legacy Surgical Procedures to More Current Bariatric Surgeries

Original Procedure	Current Procedures
Jejunocolic bypass	Jejunoileal bypass
Jejunoileal bypass	Roux-en-Y gastric bypass
Vertical and horizontal gastroplasty	Roux-en-Y gastric bypass, biliopancreatic diversion, and biliopancreatic diversion with duodenal switch
Vertical banded gastroplasty	Roux-en-Y gastric bypass, biliopancreatic diversion, and biliopancreatic diversion with duodenal switch

Various restrictive and malabsorptive procedures, or a combination thereof, have been tried clinically. The majority of these techniques are no longer performed because of associated severe complications. However, there are still patients with these procedures who are either under clinical surveillance or are being evaluated for revision or conversion to other bariatric procedures (Table 2). Knowledge of the surgical anatomy, radiologic appearance, and the associated complications is essential to the radiologist evaluating these patients.

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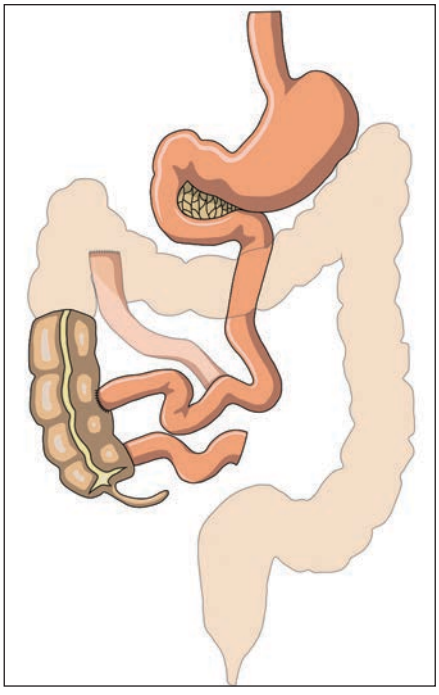


Fig. 1—Jejunocolic bypass. Drawing shows original end-to-side anastomosis of jejunum to proximal transverse colon, as well as later modification with anastomosis of jejunum to proximal ascending colon. (Drawing by Robinson TJ)

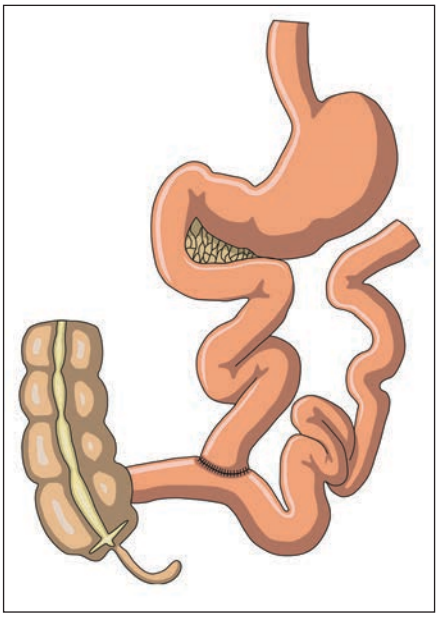


Fig. 2—Jejunoileal bypass. Drawing shows surgery originally described by Payne and DeWind [10], with anastomosis of proximal segment of jejunum to distal 10 cm of ileum. (Drawing by Robinson TJ)

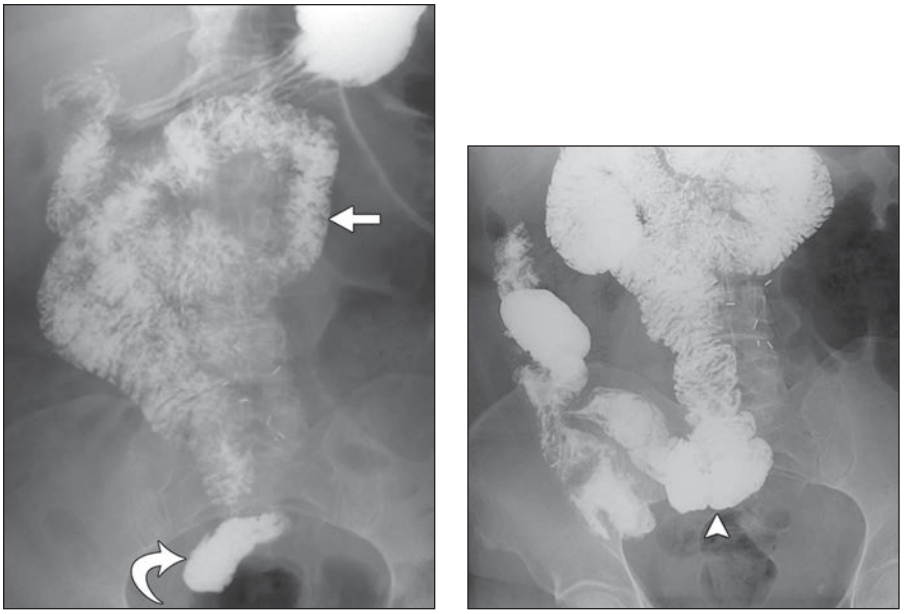


Fig. 3—40-year-old woman who underwent jejunoileal bypass surgery. Upper gastrointestinal evaluation was performed for assessment of abdominal pain and frequent diarrhea.
A, Oral contrast agent opacifies loops of proximal jejunum (*straight arrow*) and just reaches distal ileum (*curved arrow*).
B, Note end-to-end jejunoileal anastomosis (*arrowhead*).

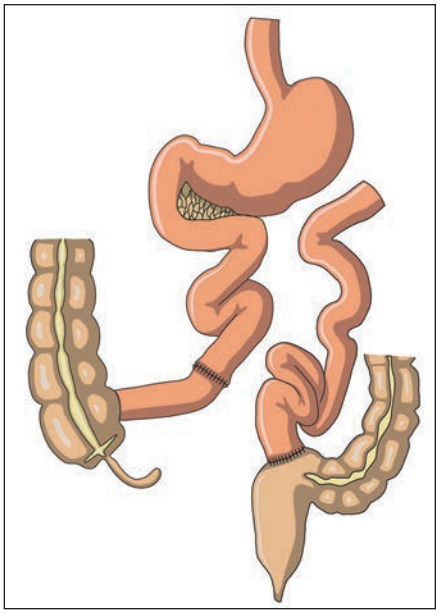


Fig. 4—Jejunoileal bypass. Drawing shows later modification by Scott et al. [11], with end-to-end anastomosis of jejunum to ileum and anastomosis of bypassed segment of small intestine to distal colon. (Drawing by Robinson TJ)

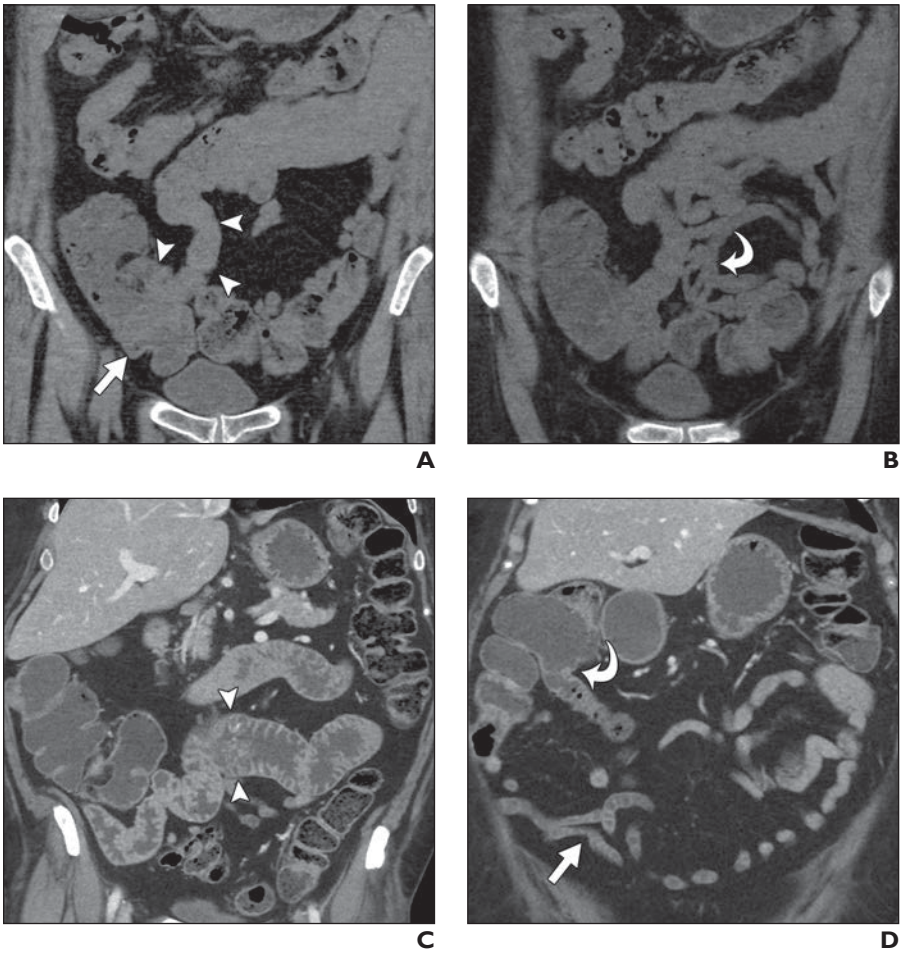


Fig. 5—Two patients with history of jejunoileal bypass surgery.
A and **B,** 66-year-old woman with remote history of bariatric surgery. CT examination was performed for assessment of unknown bowel configuration. Coronal unenhanced image (**A**) shows jejunoileal anastomosis (*arrowheads*); cecum (*arrow*) is also seen. Note collapsed atrophic ileal loops anastomosed to distal large bowel (*curved arrow*, **B**).
C and **D,** 63-year-old woman with remote history of jejunoileal bypass surgery. CT examination was performed for assessment of hematuria. Coronal reformatted image (**C**) shows jejunoileal anastomosis (*arrowheads*). Note anastomosis of bypassed small bowel to proximal transverse colon (*curved arrow*, **D**) and atrophy of bypassed segments of small bowel (*straight arrow*, **D**). Examination also showed multiple renal calculi (not shown).

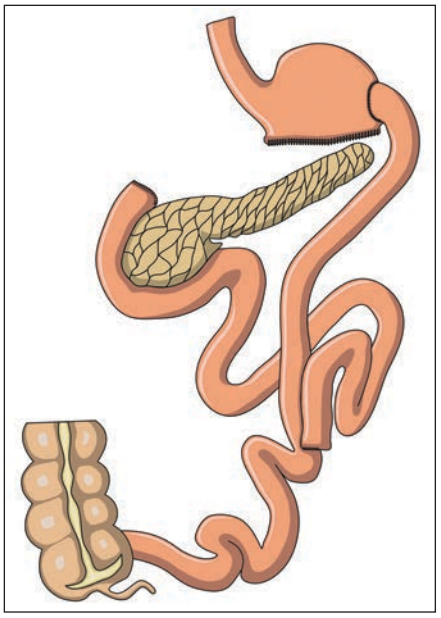


Fig. 6—Biliopancreatic diversion. Drawing shows original procedure as described by Scopinaro et al. in 1979 [16]. (Drawing by Robinson TJ)

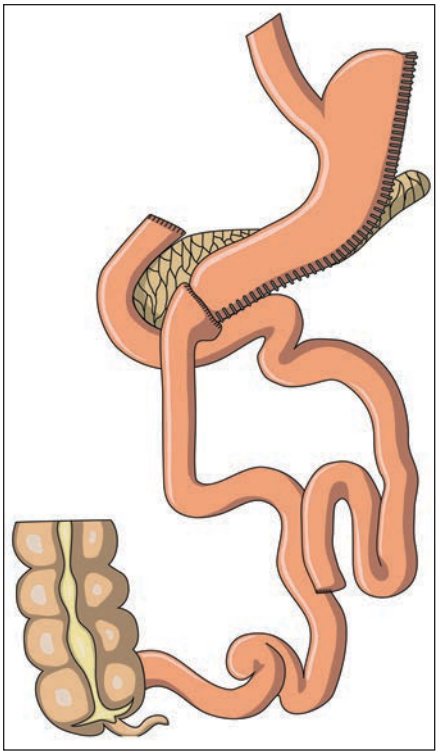
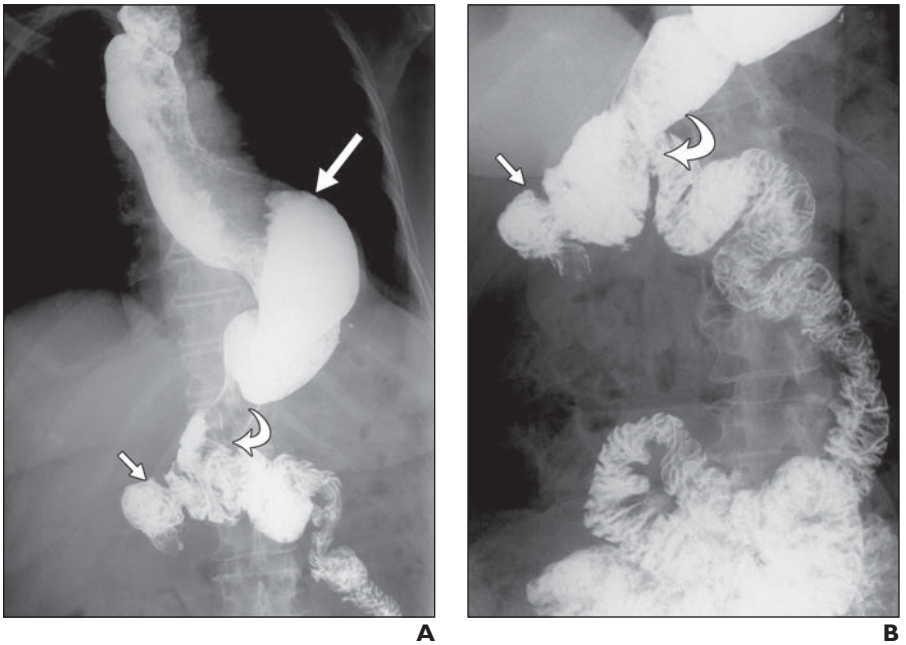


Fig. 7—Drawing depicts biliopancreatic diversion with duodenal switch, as first described by Marceau in 1993 [18]. (Drawing by Robinson TJ)



A **B**

Fig. 8—69-year-old woman with history of esophagectomy with esophagogastric anastomosis, duodenal switch, and pylorus-sparing duodenojejunostomy.
A and **B,** Upper gastrointestinal imaging shows narrowing of pylorus at duodenojejunostomy anastomosis (*curved arrows*, **A** and **B**) with restriction of contrast agent flow at this point. Note subsequent slow emptying of stomach into proximal small bowel (*long arrow*, **A**). There is reflux of ingested oral contrast agent in biliopancreatic limb (*short arrows*, **A** and **B**).

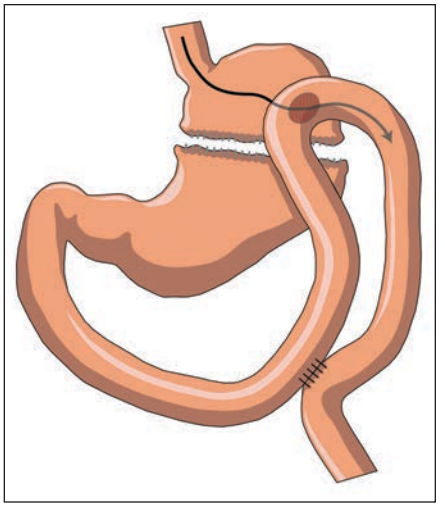


Fig. 9—Gastric bypass with loop gastrojejunostomy. Original version of this procedure involved isolation of small portion of stomach for gastrojejunostomy in undivided fashion, whereby noncutting staples were used. Over time, this procedure underwent various modifications, which included division of stomach, antecolic gastrojejunostomy, and later creation of small intestine Roux limb. (Drawing by Robinson TJ)

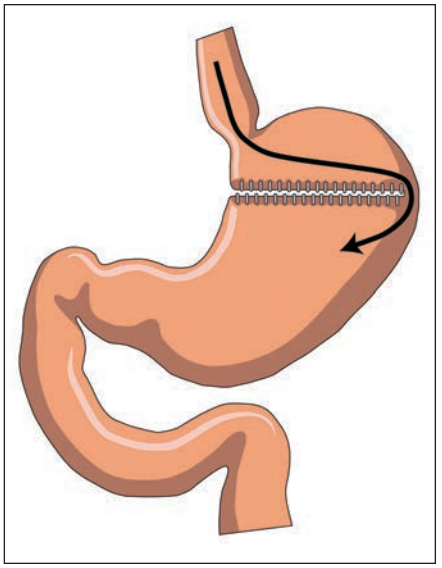


Fig. 10—Horizontal gastroplasty. Small orifice allows communication between two gastric channels. (Drawing by Robinson TJ)

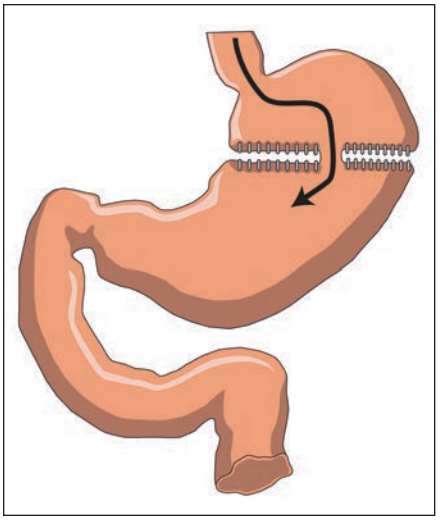


Fig. 11—Horizontal gastroplasty. Original version was modified to prevent several complications. (Drawing by Robinson TJ)

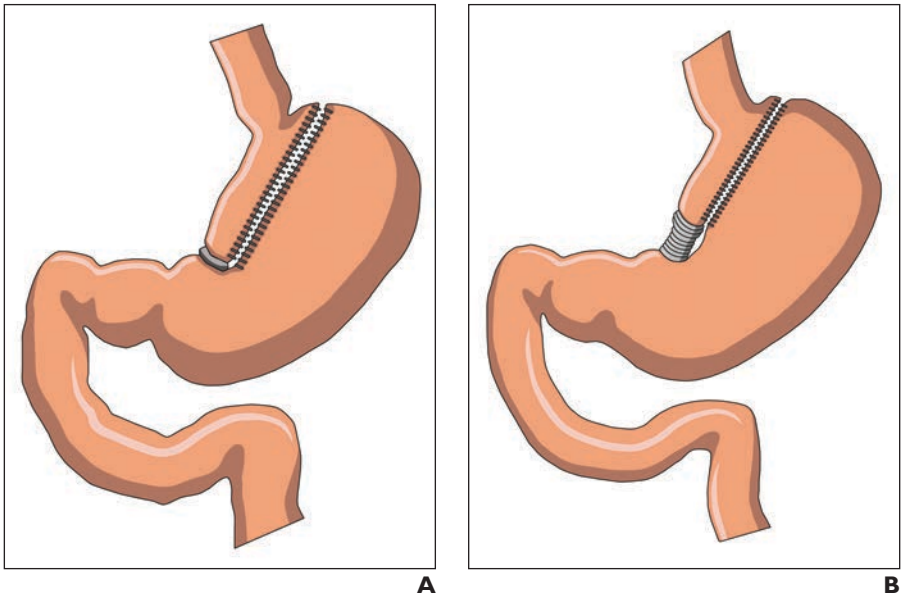


Fig. 12—Vertical banded gastroplasty.
A and **B,** Stomach is divided vertically, and small outlet is created, which is reinforced with either mesh strip (**A**) or silastic ring (**B**). (Drawings by Robinson TJ)

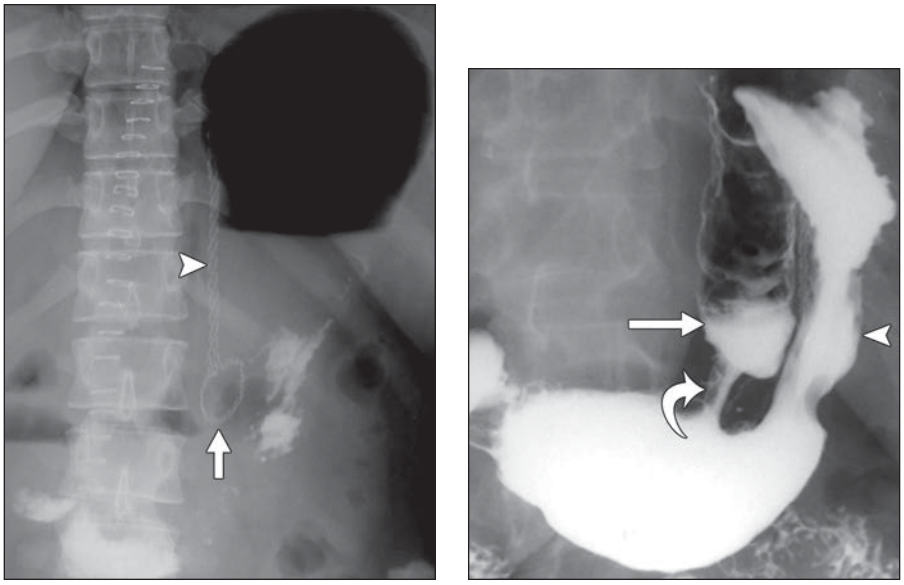


Fig. 13—40-year-old woman with history of vertical banded gastroplasty surgery. Upper gastrointestinal imaging performed for assessment of postoperative leak shows normal appearance of vertical banded gastroplasty.
A, Note vertical gastroplasty suture line (*arrowhead*) and suture line for mesh ring (*arrow*).
B, After ingestion of oral contrast agent, gastric pouch fills with contrast agent (*straight arrow*). Note passage of oral contrast agent through surgically created ring (*curved arrow*) with reflux into isolated gastric body and fundus (*arrowhead*).

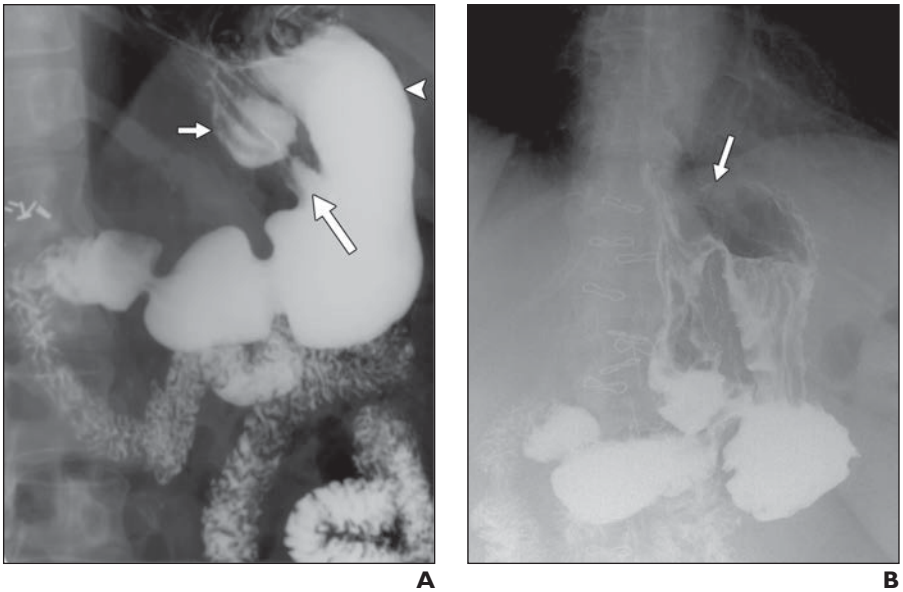


Fig. 14—Two patients with history of vertical banded gastroplasty with complaint of weight regain.
A, 35-year-old man. Upper gastrointestinal imaging shows breakdown of vertical gastroplasty suture line (*large arrow*), resulting in communication of gastric pouch (*small arrow*) and isolated segments of stomach (*arrowhead*). As consequence, patient was able to consume normal-sized meal, which resulted in weight regain.
B, 43-year-old woman. Upper gastrointestinal imaging shows proximal dehiscence of suture line, resulting in gastro-gastric fistula (*arrow*).

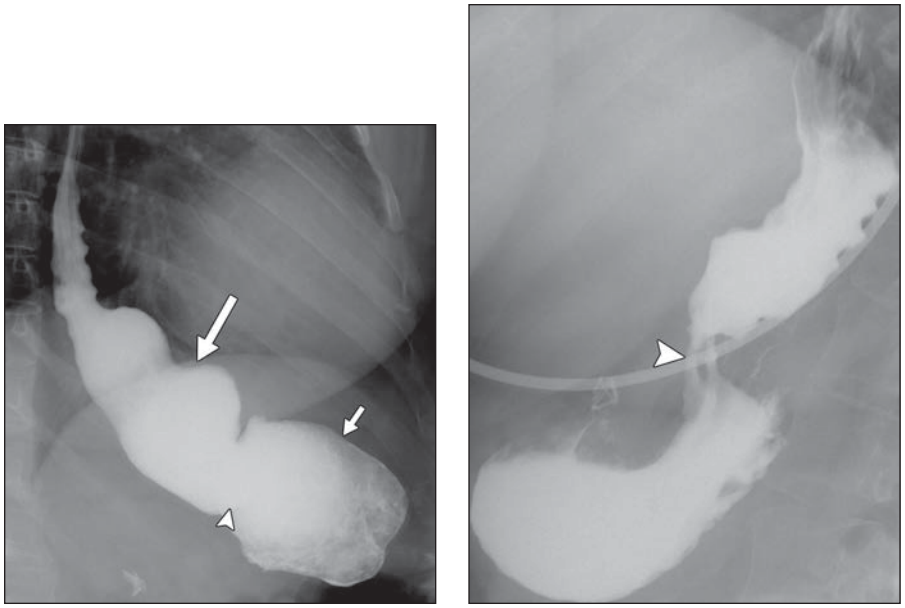


Fig. 15—49-year-old woman with history of vertical banded gastroplasty and complaint of abdominal pain.
A, Upper gastrointestinal imaging reveals high-grade obstruction of stomach (*short arrow*) at gastric banding site (*arrowhead*) and dilatation of distal esophagus (*long arrow*).
B, Balloon dilatation of vertical gastroplasty site was performed (not shown). Follow-up upper gastrointestinal imaging shows persistent mild narrowing at this site (*arrowhead*).

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