Imaging in Bariatric Surgery: A Guide to Postsurgical Anatomy and Common Complications

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OBJECTIVE. This article reviews the various bariatric surgical techniques and the associated imaging findings of normal postoperative anatomy and of common complications.

CONCLUSION. Bariatric surgery is increasingly performed to control morbid obesity secondary to failed medical approaches. As a result, imaging plays an important role in postoperative evaluation and management. Practical knowledge of postsurgical anatomy allows accurate interpretation of imaging findings related to normal postsurgical anatomy and common postsurgical complications.

Keywords: bariatric surgery, biliopancreatic diversion, biliopancreatic diversion with duodenal switch, jejunoileal bypass, laparoscopic adjustable gastric band, Roux-en-Y gastric bypass, vertical-banded gastroplasty

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Obesity is a serious, multifactorial, chronic illness affecting patients of all ages that continues to increase in prevalence at an alarming rate [1]. The most practical means of classifying obesity is the body mass index (BMI). Obesity is defined as a BMI of 30 or greater. Morbid obesity is defined as a BMI of 35 or greater with serious comorbidity or as a BMI of 40 regardless of the presence or absence of comorbidities [2].

In 2001–2004, 66% and 32% of the population between the ages of 20 and 74 years were overweight and obese, respectively. These findings reflect a nearly 40% increase in the percentage of overweight individuals and a doubling of the percentage of obese individuals over the past 22 years [3]. Various statistics have been published regarding the percentage of morbidly obese individuals in the United States, but the general consensus is that approximately 5–7% of the adult population can be considered morbidly obese [4, 5].

In 2002, financial costs directly related to increasing surgical volume in the United States were estimated to be in excess of $2 billion [6]. When comorbidities associated with morbid obesity are also considered, an estimated excess of $100 billion per year has been reported [7]. Bariatric surgery has come to the forefront in the treatment of morbid obesity as a result of research-proven effectiveness and the frustrating failure of traditional conservative methods [8–10]. Surgery also has the ability to reduce, and in some cases resolve, many comorbidities such as hypertension, type 2 diabetes, and sleep apnea [11, 12]. The success of bariatric surgery is reflected in the exponential growth of surgical volume from 2002 to 2005, increasing from an estimated 72,177 to 171,200 procedures per year [13, 14].

Bariatric Surgical Technique

Bariatric surgery is generally categorized into two main categories, restrictive and malabsorptive. In restrictive procedures, gastric volume is reduced substantially to decrease caloric intake by promoting early satiety. In malabsorptive procedures, the gastrointestinal tract is surgically altered to induce malabsorption and hence decrease caloric intake. In addition, procedures may combine techniques [15]. The spectrum of procedures includes the Roux-en-Y gastric bypass, laparoscopic adjustable gastric banding, vertical-banded gastroplasty (VBG), jejunoileal bypass, biliopancreatic diversion, and biliopancreatic diversion with duodenal switch.

Roux-En-Y Gastric Bypass

Originally introduced by Griffen et al. [16] in 1977, the Roux-en-Y gastric bypass is now the most commonly performed bariatric procedure in the United States. An estimated 88% of bariatric surgeries in the United States in 2002 were Roux-en-Y gastric bypasses [13].

Several variations are currently in use, but the general procedure involves the formation of a 15- to 30-mL gastric pouch that is surgically removed from the rest of the stomach, referred to as the remnant stomach. Formation of

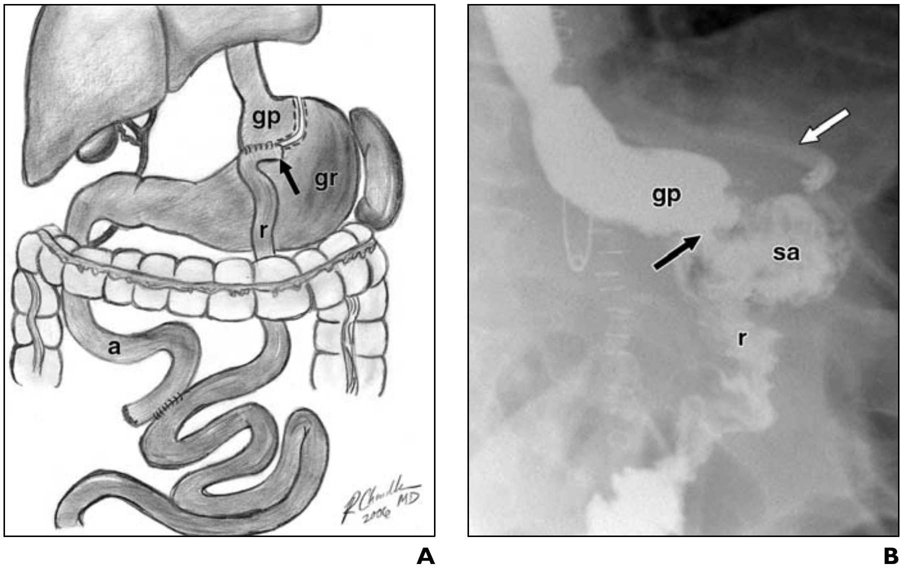


Fig. 1—Roux-en-Y gastric bypass.
A, Artistic rendering of normal postsurgical anatomy shows retrocolic Roux limb (r), gastric pouch (gp), gastric remnant (gr), afferent limb (a), and small blind afferent limb (*arrow*).
B, Anteroposterior fluoroscopic spot image shows normal postoperative anatomy in 62-year-old woman after Roux-en-Y gastric bypass: gastric pouch (gp), Roux limb (r), small blind afferent limb (sa), gastrojejunal anastomosis (*black arrow*), and surgical drain (*white arrow*).

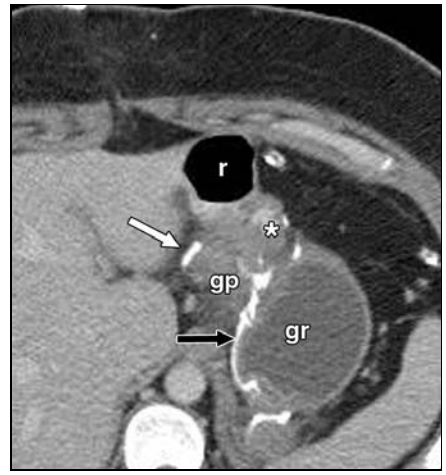


Fig. 2—Contrast-enhanced CT image in 38-year-old woman after Roux-en-Y gastric bypass shows normal postoperative anatomy: gastric pouch (gp), proximal Roux limb containing air (r), gastric suture line (*black arrow*), gastrojejunal anastomosis suture line (*white arrow*), gastric remnant containing fluid (gr), and small blind afferent limb (*asterisk*).

the pouch can involve anatomic separation by physically dividing the pouch from the remnant or by simple functional division with the application of staples. Next, the jejunum is divided approximately 30–40 cm distal from the ligament of Treitz, mobilized from the mesentery, and brought up to create a side-to-side gastrojejunostomy with the gastric pouch. This anastomosed jejunal loop is referred to as the Roux limb or efferent limb and is placed retrocolic through an opening created in the transverse mesocolon or antecolic in front of the transverse colon. Typically, a small afferent or "blind" loop is present as a result of the side-to-side approach. To complete the operation, a jejunojejunostomy is created approximately 100–150 cm distal from the gastrojejunostomy and all mesenteric defects are closed (Fig. 1A). The Roux-en-Y gastric bypass is a mixed procedure, taking advantage of both restrictive and malabsorptive components to induce weight loss. Varying the length of the Roux limb will increase or decrease the malabsorptive component [17].

Initial imaging is performed on postoperative day 1 with a Gastrografin (meglumine diatrizoate, Bracco Diagnostics) fluoroscopy study to assess for leak proximally at the gastrojejunostomy and distally at the jejunojejunostomy. The normal postoperative fluoroscopic anatomy is presented in Figure 1B. In the late postoperative setting, imaging may begin with either fluoroscopy or CT. CT is typically used when fluoroscopic examinations are equivocal and when bowel obstruction or an intraabdominal abscess is suspected. Normal postoperative findings at CT are shown in Figure 2. The retrograde flow of oral contrast material into the afferent limb and gastric remnant is common. Often gastric fluid or air can be seen in the remnant stomach as well. None of these findings involving the gastric remnant should be mistaken for abscess or gastrojejunal anastomotic leak [18, 19].

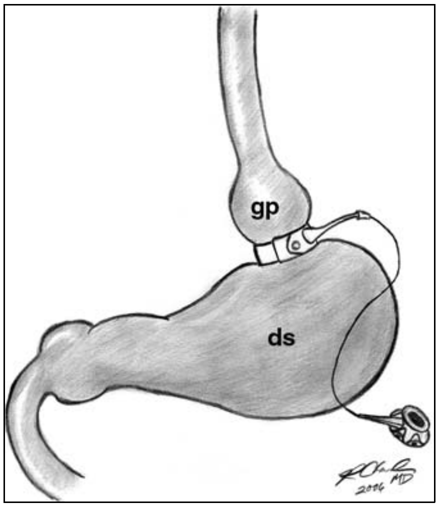
Laparoscopic Adjustable Gastric Banding

Laparoscopic adjustable gastric banding is a purely restrictive procedure that is currently the most popular surgical technique in Europe, Australia, and Latin America [20]. Since its approval by the U.S. Food and Drug Administration in 2001, however, laparoscopic adjustable gastric banding is being increasingly performed in the United States.

This surgical technique involves placing an adjustable silicon band lined with an inflatable balloon around the superior stomach to partition a small gastric pouch and create an adjustable stoma into the remainder of the stomach. The anterior gastric wall is often sutured over the band to the gastric pouch to decrease the chances of band slippage. The balloon is then connected via tubing to a port placed subcutaneously in the abdomen (Fig. 3A). Through aspiration or injection of saline into the port, the size of the band is decreased or increased, and hence the diameter of the gastric stoma adjusted [21, 22].

On postoperative day 1, patients undergo fluoroscopic evaluation to assess gastric pouch size for possible contrast extravasation from occult iatrogenic gastric injury and for unhindered passage of orally administered contrast material into the remainder of the stomach via the surgically created stoma. The gastric pouch should be relatively symmetric in shape and measure approximately 3–4 cm in maximum dimension when distended with contrast material. The stoma should measure approximately 3–4 mm in diameter, and contrast material should empty from the pouch 15–20 minutes after contrast administration [23].

Another factor assessed on every fluoroscopic examination is the phi angle. The phi angle is created by intersecting a line drawn parallel to the spinal column with a line drawn parallel to the plane of the gastric band, on an anteroposterior projection. Normally, this angle should range from 4° to 58° and lie approximately 4–5 cm below the left hemidiaphragm [24]. Normal postoperative fluoroscopic anatomy is shown in Figure 3B. CT is not usually indicated for early postoperative evaluation.



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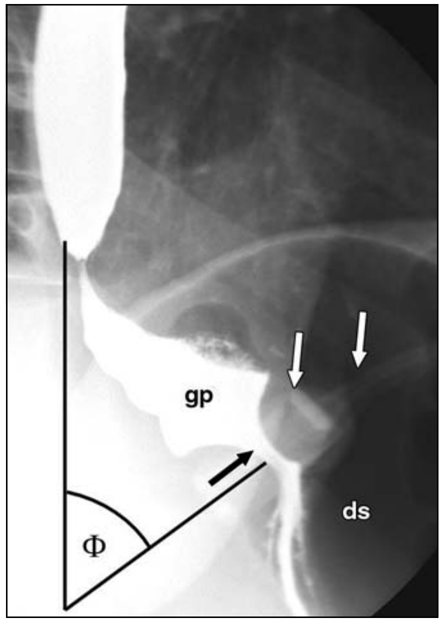

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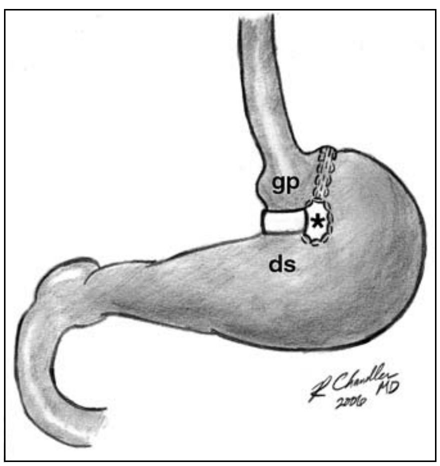
Fig. 3—Laparoscopic adjustable gastric banding.
A, Artistic rendering of normal postsurgical anatomy shows band around superior gastric body and connection to access port, which is placed subcutaneously. gp = gastric pouch, ds = distal stomach.
B, Anteroposterior fluoroscopic spot image in 43-year-old woman after laparoscopic adjustable gastric banding shows normal postoperative anatomy. Note gastric pouch (gp), adjustable band with tubing (*white arrows*), gastric stoma (*black arrow*), and distal stomach (ds). Phi angle (Φ) is normal.



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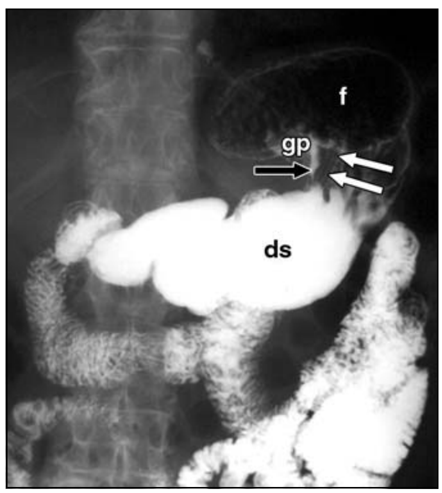

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Fig. 4—Vertical-banded gastroplasty (VBG).
A, Artistic rendering of normal postsurgical anatomy shows creation of small gastric pouch (gp) by vertical stapling and application of polypropylene band through transgastric window (*asterisk*). ds = distal stomach.
B, Anteroposterior overhead image from fluoroscopy in 69-year-old woman after VBG shows normal postoperative anatomy, including gastric pouch (gp), gastric stoma (*black arrow*), distal stomach (ds), air-filled fundus (f), and suture line (*white arrows*).

Vertical-Banded Gastroplasty

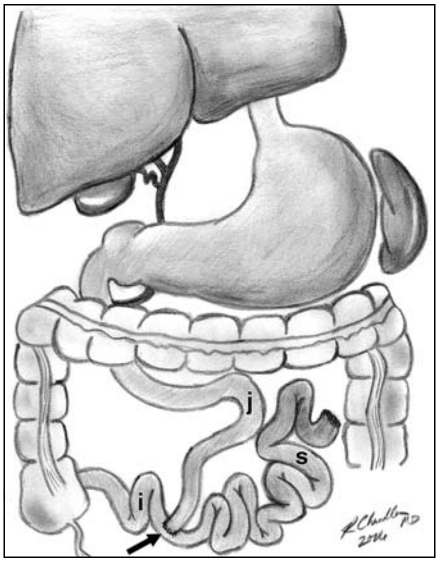
VBG is an older, purely restrictive procedure originally introduced by Mason [25] in 1982. Currently, the VBG has decreased significantly in prevalence with the popularity of the Roux-en-Y gastric bypass, the advent of laparoscopic adjustable gastric banding, and problems with long-term weight loss [26, 27].

Mason's technique for VBG involves creating a small gastric pouch, based on the lesser curvature of the stomach, by using a stapler to vertically partition the stomach. The lesser curvature is used because it is thicker and less resistant to stretching than the greater curvature [28]. Using a circular stapler, the anterior and posterior walls of the stomach are then stapled together and an incision is made through the excluded gastric walls to create a circular window. Finally, a polypropylene mesh band is wrapped around the stomach and placed through the window to create a small proximal gastric pouch and a small stoma into the remainder of the stomach (Fig. 4A).

Initial postoperative imaging is performed with fluoroscopy to assess for contrast extravasation, staple line competence, and gastric pouch size; and for unhindered passage of orally administered contrast material through the surgically created stoma. Normal postoperative fluoroscopic anatomy is shown in Figure 4B. Similar to laparoscopic adjustable gastric banding, imaging with CT is not usually indicated for early postoperative evaluation.

Jejunoileal Bypass

Created by Kremen et al. [29] in 1954, the jejunoileal bypass (JIB) was the original bariatric surgical procedure. Today, the JIB has long since been abandoned because of the severe malnutritional state and resultant side effects it induced [30–33]. Despite the demise of the JIB, patients who underwent the procedure still exist, and therefore knowledge of the procedure is important to radiologic imaging.



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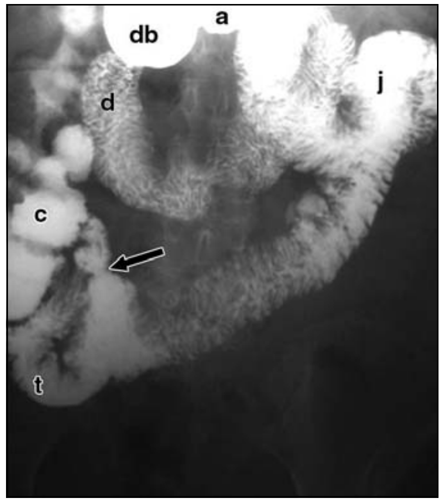


B

Fig. 5—Jejunoileal bypass.
A, Artistic rendering of normal postsurgical anatomy shows creation of distal end-to-side jejunoileostomy (*arrow*) and resultant bypass of large portion of small bowel. Note ileum (i), proximal jejunum (j).
B, Anteroposterior overhead image from fluoroscopy in 67-year-old woman after jejunoileal bypass shows normal postoperative anatomy, including gastric antrum (a), duodenal bulb (db), duodenum (d), jejunum (j), terminal ileum (t), cecum (c), and region of jejunoileal anastomosis (*arrow*).

TABLE 1: Complications of Roux-en-Y Gastric Bypass

Complication	Incidence (%)	Time Period[a]
Anastomotic leak	2–5	Early
Stricture		
Gastrojejunal anastomotic	3–9	Late more than early
Jejunojejunal anastomotic	< 1	Late more than early
Obstruction (all causes)	1–5	Late more than early
Mesocolic window stenosis	1–2	Late more than early
Transmesenteric herniation (all forms)	2.2	Late more than early
Intussusception	Extremely rare	Late
Hernia		
Incisional	3.5–14.6	Early or late
Internal (all forms)	3.0	Late
Trocar	0.3–1.2	Late more than early
Gastric staple line disruption	0.7–8.3	Late more than early
Wound infection	Up to 10	Early
Blind pouch syndrome	Rare	Late
Marginal ulceration	0.5–4.0	Late

[a]"Early" and "late" refer to complications occurring during first month and > 1 month after surgery, respectively.

Variations exist; however, the general procedure involves dividing the proximal jejunum and then performing an end-to-side jejunoileostomy with a short jejunal limb approximately 35 cm long anastomosed to the terminal ileum, approximately 10 cm proximal to the ileocecal valve (Fig. 5A). Nearly 90% of the small bowel is excluded.

Radiologic evaluation is generally performed first with fluoroscopy to assess for possible anastomotic stricture, ulceration, or obstruction of the efferent loop. The normal postoperative fluoroscopic anatomy is shown in Figure 5B. In equivocal cases, further evaluation with contrast-enhanced CT is often performed. In many patients who have persistent complications, conversion is often necessary, with JIB takedown and formation of either a Roux-en-Y gastric bypass or VBG [34–36].

Complications of Bariatric Surgery

Roux-en-Y Gastric Bypass

Anastomotic leak—Table 1 lists complications associated with the Roux-en-Y gastric bypass. Table 2 lists CT findings in complications of the Roux-en-Y gastric bypass. Regardless of laparoscopic or open technique, the most serious complication is anastomotic leak. Most often occurring at the gastrojejunal anastomosis, leak has a reported occurrence of approximately 2–5% of patients undergoing the procedure [37–40]. Early detection of leak is essential to prevent rapid development of sepsis and, in some cases, death. Both radiologist and surgeon should have a high degree of suspicion for leakage; the clinical picture is often misleading because bariatric patients with peritonitis may not have fever, abdominal pain or tenderness, or an elevated WBC. Of all manifestations of intraabdominal sepsis, tachycardia with a pulse exceeding 120 beats per minute has been reported to be the most consistent and reliable finding on physical examination [38].

Fluoroscopy typically shows extravasated radiologic contrast material in the left upper quadrant from leakage at the gastrojejunal anastomosis (Fig. 6A). Sometimes fluoroscopic imaging before the administration of contrast material may show a collection of air in the left upper quadrant, although this finding can be difficult to ascertain because of body habitus.

Two potential pitfalls in evaluation for leak should be noted. First, with open Roux-en-Y gastric bypass a nasogastric tube is often placed with the distal end in the Roux limb to act as a temporary stent at the gastrojejunal anastomosis, combating early postoperative edema. Fluoroscopy should include imaging

TABLE 2: CT Findings of Roux-en-Y Gastric Bypass Complications

Complication	Findings
Anastomotic leak	Contrast extravasation
	Air–fluid levels adjacent to site of leakage
	Air and contrast material tracking along surgical drains
	Possible phlegmon or abscess formation
Gastrojejunal anastomotic stricture	Dilatation of gastric pouch
	Possible esophageal reflux of contrast material
	Possible gastric outlet obstruction
	Compression of gastric remnant
Jejunojejunal anastomotic stricture	Dilatation of Roux limb with fluid, air, and contrast material
	Possible gastric pouch dilatation
	Possible dilatation of afferent limb secondary to refluxed contrast material into duodenum and remnant stomach
	Possible obstruction of Roux limb or afferent limb
	Normal-caliber small bowel distal to anastomosis
	Possible esophageal reflux
Mesocolic window stenosis	Dilatation of Roux limb near jejunojejunal anastomosis
	Normal-caliber afferent limb
	Possible gastric pouch dilatation and esophageal reflux
Transmesenteric herniation	Dilated, clustered small-bowel loops
	No omental fat overlying dilated small-bowel loops
	Engorgement and stretching of mesenteric vessels
	Possible closed-loop small-bowel obstruction
	Obstruction of Roux limb
	Possible central displacement of transverse colon
Intussusception	Classic target sign
	Proximal obstruction of small bowel or gastric pouch, depending on location
	Possible obstruction of afferent limb with jejunojejunal location
Gastric staple line disruption	Dense contrast material and air in gastric remnant
	CAUTION: Better diagnosed with fluoroscopy because reflux of contrast material into gastric remnant via afferent limb can simulate staple line disruption on CT
Blind pouch syndrome	Focal dilated segment of bowel adjacent to suture line or clips
	Normal intervening small bowel
	No obstruction proximally

after the nasogastric tube has been pulled back because the tube can prevent visualization of leakage from the anastomosis [41]. Second, infrequently the only fluoroscopic evidence of leak may be opacification of a surgical drain, which may be missed if the radiologist is focused on watching for irregular contrast pooling outside the gastrointestinal pathway [42]. CT often shows tracking of oral contrast material along the surgical drain (Fig. 6B). Although much less frequent, leak can also occur at the jejunojejunal anastomosis, the short jejunal afferent portion of the Roux limb, the esophagus, the blind-ending afferent jejunal limb, and the gastric pouch.

Anastomotic stricture—Anastomotic stricture commonly occurs at the gastrojejunal anastomosis and rarely at the jejunojejunal anastomosis. The reported incidence at the gastrojejunal anastomosis ranges from 3% to 9% [43, 44]. Stricture may occur early, within days, secondary to ischemia or edema; or stricture may manifest late, after months or years, most often as a result of adhesions [19, 43].

Fluoroscopy shows narrowing at the gastrojejunal anastomosis, resultant expansion of the gastric pouch, and delayed transit of contrast material into the Roux limb (Fig. 7). In all cases but one of gastrojejunal anastomotic stricture at our institution, the cause was early postsurgical edema that resolved on subsequent fluoroscopic examinations. The one exception was a patient who had undergone Roux-en-Y gastric bypass several years earlier and presented with persistent nausea and vomiting; dilatation of the gastric pouch secondary to extensive adhesions was shown on CT (Fig. 8).

Infrequently, there may be stricture at the jejunojejunal anastomosis; the reported incidence is 0.8% [45]. Presenting symptoms are generally the same as with gastrojejunal stenosis, with the addition of diffuse abdominal pain secondary to dilatation of the afferent limb. On fluoroscopic and CT examinations, contrast material is seen in a distended Roux limb with possible retrograde flow into the afferent limb and remnant stomach (Fig. 9). Depending on the severity, dilatation of the gastric pouch and gastroesophageal reflux may be seen.

Ileus and obstruction—Postoperative adynamic ileus is a common finding typically seen on fluoroscopic examination performed on postoperative day 1 to assess for leak. The expected finding of uniformly dilated bowel coated with contrast material is easily recognized.

Obstruction, with a reported incidence of up to 5% [40, 41, 46], may occur in several locations and may result from several mechanisms. Potential sites include the gastrojejunostomy site, the jejunojejunostomy site, the mesocolic window, and behind the Roux limb (Peterson's space). In the early postoperative setting, obstruction is often due to severe edema and will resolve spontaneously [47]; early obstruction can also result from iatrogenic stenosis secondary to overzealous suturing. In the late postoperative setting, obstruction may result from fibrotic stenosis, internal hernias, adhesions, and, rarely, intussusception [40]. In addition, obstruction can result from external herniation in the early or late postoperative setting. Almost any combination of the aforementioned mechanisms and locations can occur. Figure 10 shows fluoroscopic findings in a patient with partial gastric outlet obstruction at the gastrojejunal anastomosis secondary to stricture.

In patients with retrocolic placement of the Roux limb, obstruction may result from

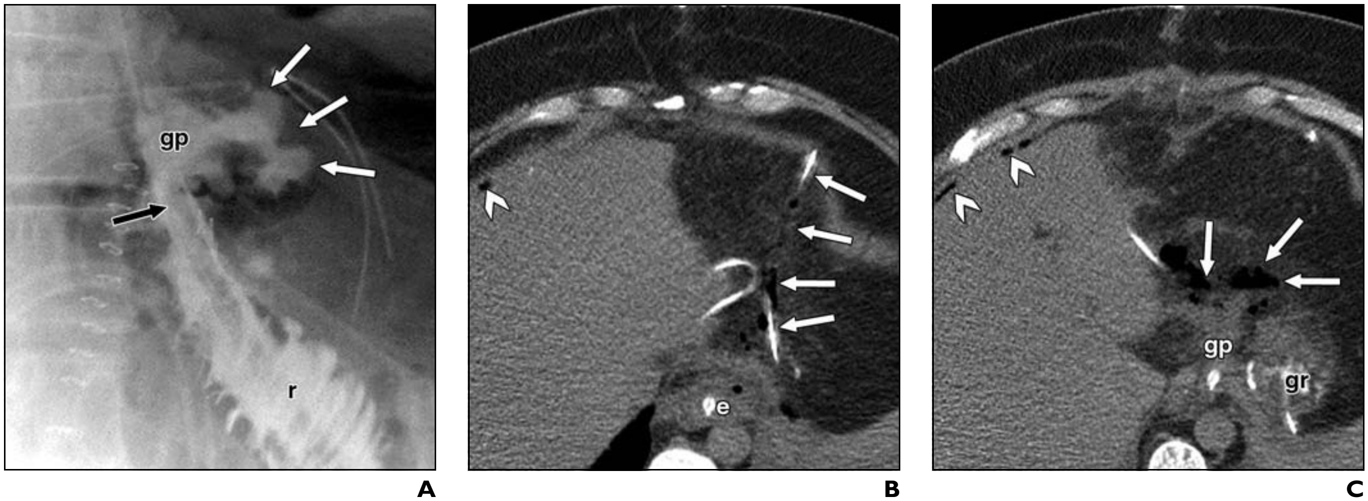


Fig. 6—43-year-old man with gastrojejunal anastomotic leak 8 days after Roux-en-Y gastric bypass.
A, Anteroposterior fluoroscopic spot image shows extravasated contrast material (*white arrows*), gastric pouch (gp), Roux limb (r) containing nasogastric tube, and gastrojejunal anastomosis (*black arrow*). Patient was observed and leak was sealed off without surgical intervention.
B and **C,** Sequential CT images show extravasated contrast material and air (*arrows,* **B**) tracking along surgical drain, air–fluid levels (*arrows,* **C**) anterosuperior to gastric pouch (gp), peripheral pneumoperitoneum (*arrowheads*), and refluxed contrast material in gastric remnant (gr). Nasogastric tube is seen in esophagus (e). Patient was observed and the leak sealed off without surgical intervention.

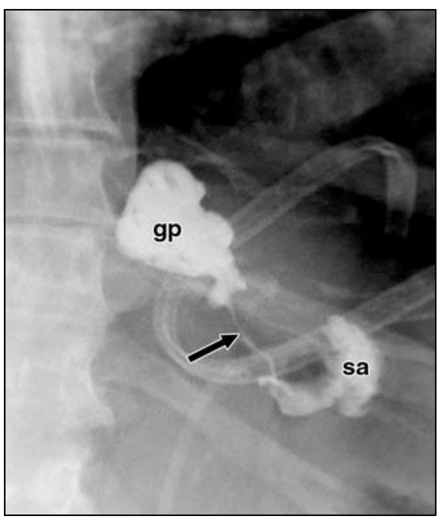


Fig. 7—Anteroposterior fluoroscopic spot image in 42-year-old woman after Roux-en-Y gastric bypass who had gastrojejunal anastomotic stricture secondary to early postoperative edema that resolved spontaneously shows severe narrowing of gastrojejunal anastomosis (*arrow*) and enlargement of gastric pouch (gp). Note short afferent portion of Roux limb (sa).

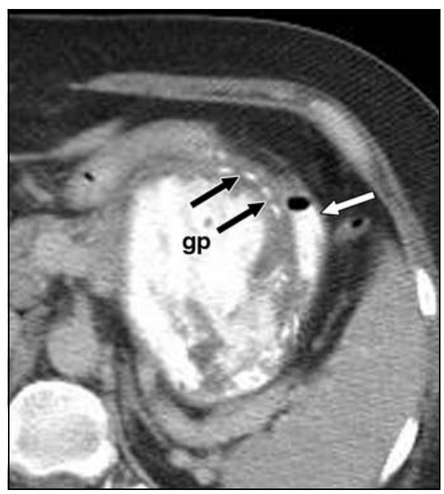
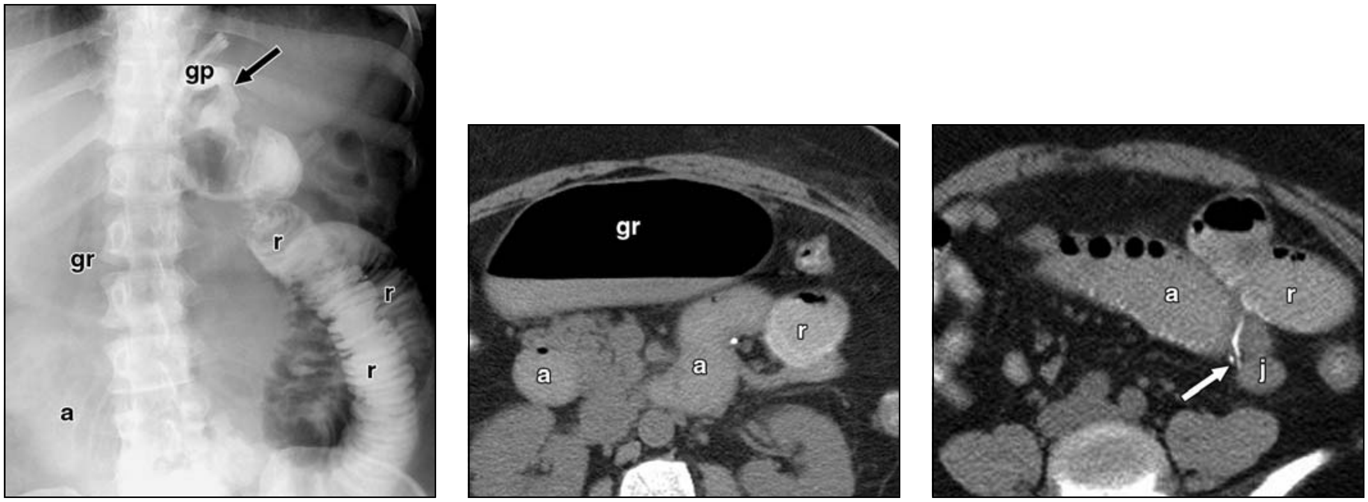


Fig. 8—Contrast-enhanced CT image in 52-year-old woman after Roux-en-Y gastric bypass who had gastrojejunal anastomotic stricture secondary to adhesions. CT scan shows marked enlargement of gastric pouch (gp), which is compressing gastric remnant (*white arrow*). Note gastric staple line (*black arrows*). Diagnostic laparotomy confirmed findings. Adhesions were lysed and 10-French feeding tube was placed because of dysphagia due to multiple medical problems.

mesocolic window stenosis or transmesenteric hernia. Mesocolic window stenosis occurs in 1–2% of cases [48] after Roux-en-Y gastric bypass and may occur in the early or late postoperative setting. Fluoroscopy reveals marked distention of the Roux limb proximal to the expected location of the mesocolic window with varying degrees of passage of oral contrast material distally, depending on the degree of obstruction (Fig. 11). Antecolic placement of the Roux limb will obviate the possibility of mesocolic window complications; yet the potential for the rare Peterson hernia persists [49].

Transmesenteric herniation has been reported in approximately 2.2% of patients undergoing Roux-en-Y gastric bypass [50]. Herniation occurs when varying amounts of small bowel and its associated mesentery are pulled through a mesenteric defect. Diagnosis is imperative because the herniated bowel may twist within the hernia sac, resulting in volvulus and a predisposition to bowel ischemia [44]. Herniation of the Roux limb through the mesocolic window is most common. However, herniation of distal small bowel through a jejunojejunal mesenteric defect can develop if the defect was incompletely sutured or if spontaneous reopening occurs. With mesocolic window herniation, fluoroscopy will show dilatation of the Roux limb with multiple distended loops. Depending on the degree of herniation, mass effect on the transverse colon may also be observed. Sometimes the Roux limb will herniate to the extent that the jejunojejunal anastomosis is pulled through the mesocolic window with resultant obstruction of the afferent limb as well (Fig. 12). With transmesenteric herniation at any location, CT often shows small-bowel obstruction, clustered small-bowel loops, central displacement of the colon, no overlying omental fat, displacement of the mesenteric



A B C

Fig. 9—55-year-old woman with jejunojejunal anastomotic stricture 1 week after Roux-en-Y gastric bypass surgery.
A, Overhead image from fluoroscopic examination shows distention and opacification of Roux limb (r) and air distending afferent limb (a), which is partially coated with contrast material. Note air-distended gastric remnant (gr), gastric pouch (gp), and gastrojejunal anastomosis (*arrow*). Patient underwent percutaneous decompression and resolution of gastric remnant by interventional radiology department, which precluded surgery.
B and **C,** CT scans show site of stricture at jejunojejunal anastomosis (*arrow,* **C**) and dilated proximal afferent loop (a), distended gastric remnant (gr), distended Roux limb (r), and normal-caliber distal jejunum (j). Percutaneous decompression of gastric remnant by interventional radiology department precluded surgery.

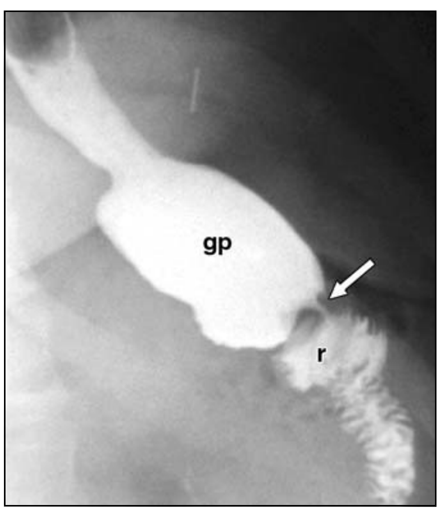


Fig. 10—38-year-old woman with partial gastrojejunal anastomotic obstruction secondary to stricture 3 weeks after Roux-en-Y gastric bypass .Fluoroscopic spot image taken 15 minutes after contrast administration shows distention of gastric pouch (gp) and severely delayed passage of contrast material past narrowed gastrojejunal anastomosis (*arrow*). Note Roux limb (r). Esophagogastroduodenoscopy confirmed findings, and uncomplicated balloon dilatation was performed.

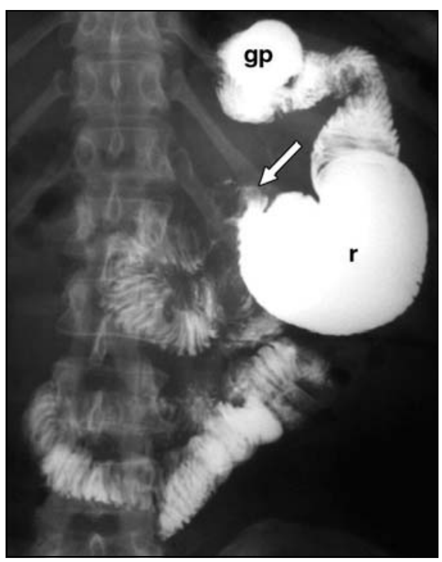


Fig. 11—44-year-old woman with mesocolic window obstruction secondary to adhesions 5 weeks after Roux-en-Y gastric bypass .Overhead image from fluoroscopic examination shows dilatation of Roux limb (r) proximal to expected location of mesocolic window (*arrow*). Note gastric pouch (gp). Diagnostic laparotomy confirmed extensive circumferential adhesions constricting Roux limb at mesocolic window.

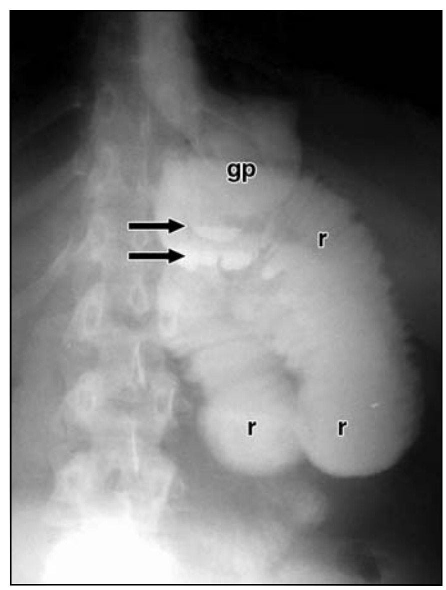


Fig. 12—32-year-old woman with obstruction secondary to mesocolic window hernia 4 weeks after Roux-en-Y gastric bypass .Overhead image from fluoroscopic examination shows distention and herniation of entire Roux limb (r) above expected region of mesocolic window, air–contrast levels (*arrows*), and distended gastric pouch (gp). Exploratory laparotomy confirmed complete herniation of Roux limb and jejunojejunal anastomosis through mesocolic window.

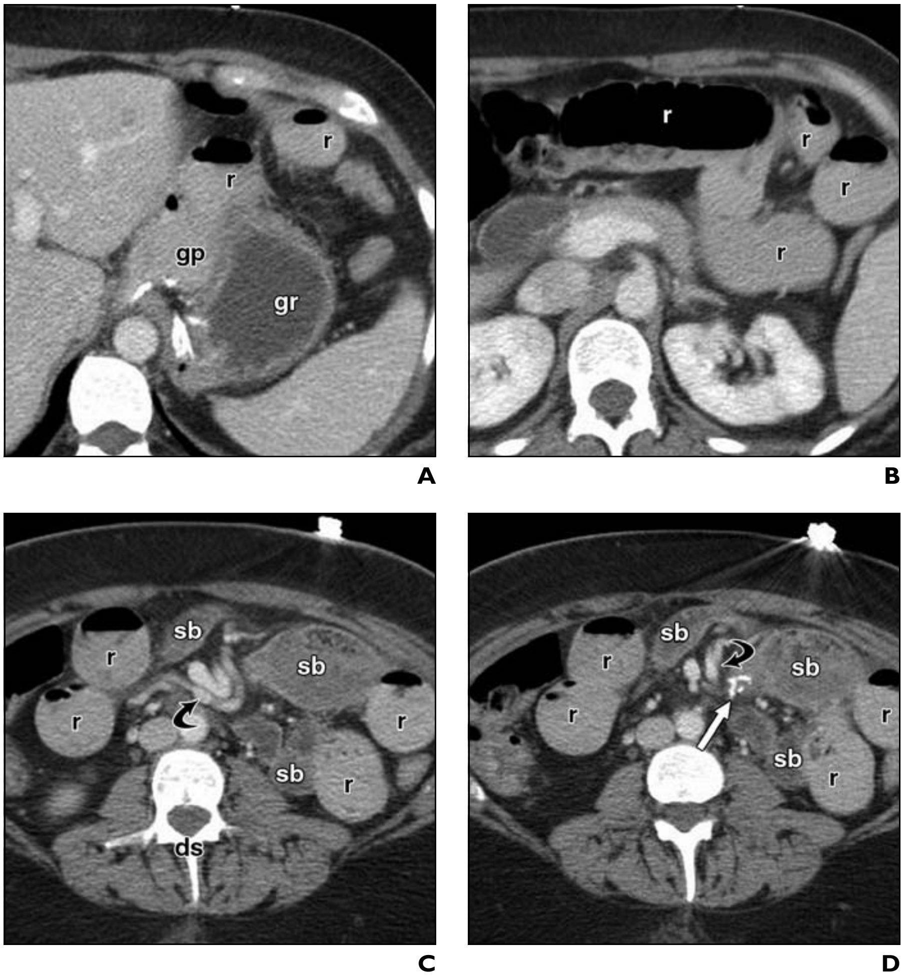


Fig. 13—41-year-old woman with transmesenteric herniation of distal small bowel (sb) through mesenteric defect at jejunojejunal anastomosis site (*straight arrow,* **D**) 6 year after Roux-en-Y gastric bypass.
A–D, CT scans show associated mesenteric vessels are stretched and engorged (*curved arrow,* **C** and **D**). Obstruction of Roux limb (r) secondary to extrinsic compression by herniated small-bowel loops is also present. Note gastric pouch (gp) and gastric remnant (gr). Diagnostic laparoscopy confirmed CT findings. Herniated small bowel (sb) was viable, reduction was performed with atraumatic graspers, and responsible mesenteric defect was closed laparoscopically. ds = distal stomach.

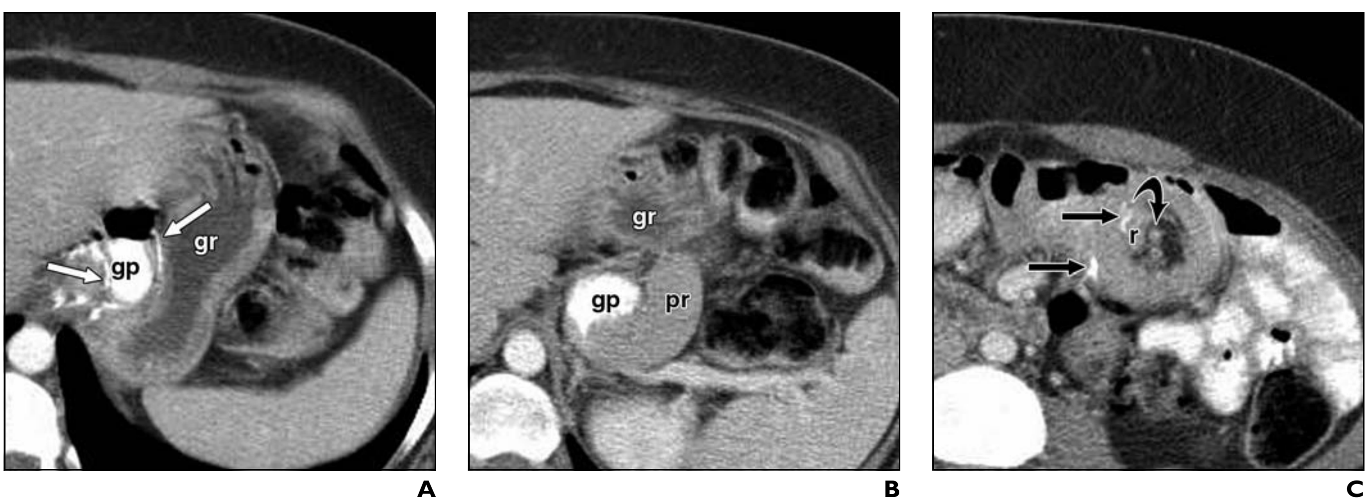


Fig. 14—25-year-old woman with jejunojejunal intussusception just proximal to jejunojejunal anastomosis (*straight arrows,* **A** and **C**) 3 year after Roux-en-Y gastric bypass.
A–C, CT scans show classic target sign involving distal Roux limb (r) and resultant mild dilatation of proximal portion (pr) of the Roux limb. Note gastric pouch (gp), gastric remnant (gr), gastric suture line (*white arrows*), and mesenteric vessels (*curved arrow*).

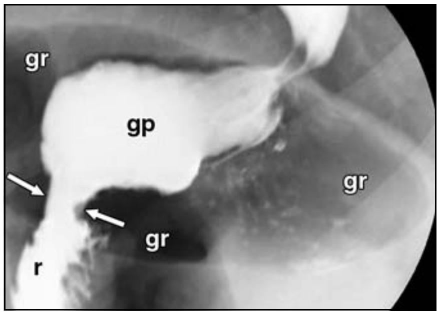


Fig. 15—42-year-old woman with gastric staple line disruption after Roux-en-Y gastric bypass .Oblique spot image from fluoroscopic examination shows air and contrast material in gastric remnant (gr). Note gastric pouch (gp) and Roux limb (r). Also note gastrojejunal anastomosis (*arrows*). Diagnostic laparotomy confirmed findings; adhesion lysis and staple line revision were performed.

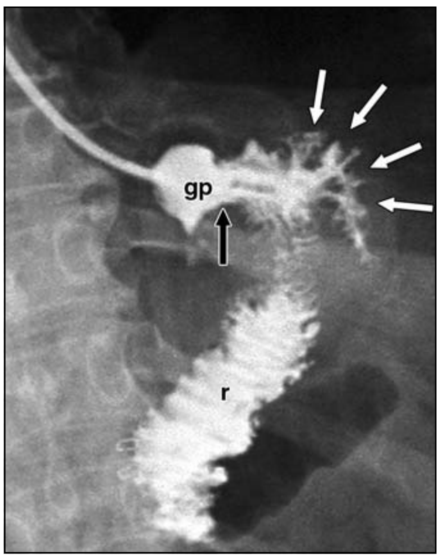


Fig. 16—57-year-old woman with filling of oversewn jejunum after Roux-en-Y gastric bypass. Fluoroscopic image shows filling of short oversewn afferent jejunal limb (*white arrows*), gastrojejunal anastomosis (*black arrow*), gastric pouch (gp), and Roux limb (r). Note tip of nasogastric tube in proximal Roux limb and normal jejunal fold pattern.

TABLE 3: Complications of Laparoscopic Adjustable Gastric Banding

Complication	Incidence (%)	Time Period[a]
Band-related		
Band slippage	2.3–13	Late more than early
Band misplacement	2.3	Early
Band erosion into stomach	3	Late
Iatrogenic band overinflation and resultant stenosis	Unknown	Early or late
Stomal stenosis	8–11	Early or late
Gastric necrosis	Rare	Late
Gastric volvulus and severe band slippage	Rare	Late
Pouch dilatation	3–8	Late more than early
Gastric perforation	0.1–0.8	Early
Port-related		
Infection	< 1	Early more than late
Port rotation and inversion	1–5	Late more than early
Tubing disconnection	1–5	Late
Leak from port–tubing connection	1–5	Late

[a]"Early" and "late" refer to complications occurring during first month and > 1 month after surgery, respectively.

trunk, and engorgement and stretching of the mesenteric vessels [51]. With herniation through a jejunojejunal mesenteric defect, the herniated small bowel may also extrinsically compress the Roux limb near the jejunojejunal anastomosis, resulting in obstruction (Fig. 13).

Differentiation of mesocolic window stenosis from transmesenteric herniation is based on two findings: the afferent loop is not distended in mesocolic window stenosis, and the Roux limb is dilated to a transition point proximal to the jejunojejunostomy site in mesocolic window stenosis [19].

Intussusception after Roux-en-Y gastric bypass is exceedingly rare, with only 11 reported cases in the literature [52, 53]. The exact cause is unknown; however, various theories propose the possibility of lead points from suture lines, adhesions, lymphoid hyperplasia, and submucosal edema [52]. Electrolyte imbalance, ectopic gut pacemaker foci, chronic bowel dilatation, and altered bowel motility have also been suggested [54]. Regardless of cause, intussusception is usually retrograde and located at or just distal to the jejunojejunostomy. CT shows the classic target sign consisting of the invaginating bowel segment (intussusceptum) and its mesentery telescoping into the lumen of the receiving bowel segment (intussuscipiens). With obstruction, varying degrees of proximal dilatation of the Roux limb, afferent limb, gastric remnant, and gastric pouch will be seen (Fig. 14).

Gastric staple line disruption—Disruption of the staple line used to separate the gastric pouch from the remnant stomach has varying incidences reported in the literature, ranging from 0.7% to 8.3% [18, 55]. Disruption can occur early secondary to suboptimal surgical technique or gastric ischemia. Disruption can also occur in the late postoperative period as a result of patient noncompliance with small meals and resultant distention of the gastric pouch and elevated tension on the staple line. Evaluation is best performed with fluoroscopy because with CT it is difficult to assess whether contrast material in the remnant stomach occurred as a result of the staple line disruption or from retrograde flow through the afferent limb [42].

Findings at fluoroscopy are determined by the specific method of gastric pouch formation. With anatomic division of the stomach, examination findings will be no different from any other leak, with extravasation of contrast material into the peritoneal cavity. Clinically, the patient may present with peritoneal signs. With functional division, in which the stomach remnant is not physically divided from the gastric pouch, contrast material and air will be seen filling both the gastric pouch and the remnant stomach (Fig. 15). Evaluation will also show eventual filling of the gastric antrum, duodenal bulb, and afferent limb. Clinically, the patient may present with failure to lose weight and loss of early satiety, although if the disruption is small it may remain subclinical until it is incidentally found [41].

A potential pitfall encountered when assessing for staple line disruption is filling of the short stump of oversewn jejunum at the gastrojejunal anastomosis. Sometimes contrast material will opacify this short segment of jejunum, which can mimic leakage into the gastric remnant (Fig. 16). Distinguishing features include lack of contrast progression into the gastric antrum and afferent loop and visualization of jejunal plicae.

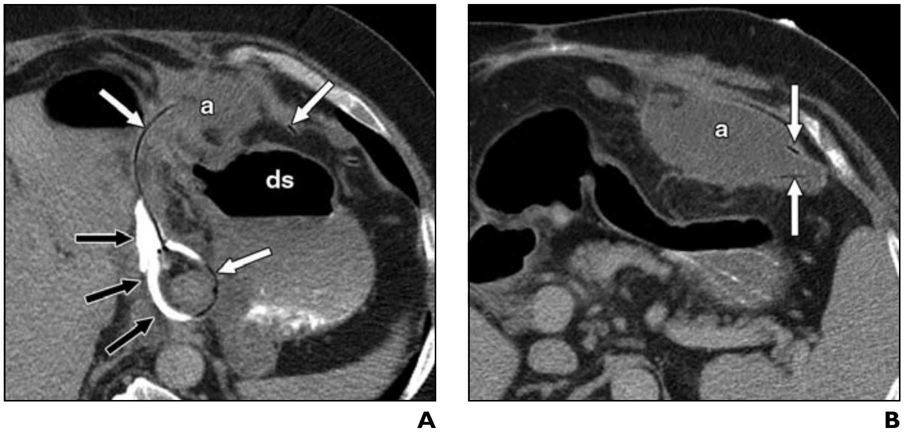


Fig. 17—39-year-old man with abscess 21 days after laparoscopic adjustable gastric banding.
A and **B,** CT series shows intraabdominal abscess (a) tracking along band tubing (*white arrows*). Note adjustable gastric band (*black arrows*) and distal stomach (ds). At laparotomy, fistula between subcutaneous port site and lesser sac was found. Band and port were removed.

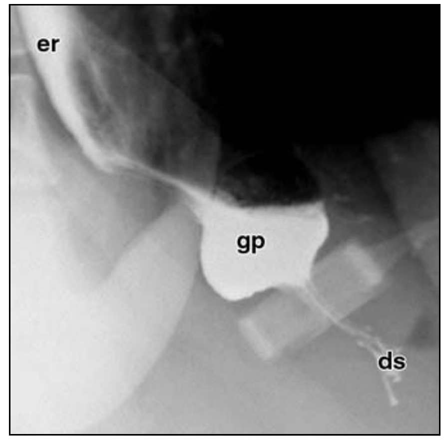


Fig. 19—43-year-old woman with dysphagia secondary to gastric stomal stenosis 4 years after laparoscopic adjustable gastric banding .Fluoroscopic spot image taken 20 minutes after contrast administration shows mildly distended gastric pouch (gp) with air–contrast level and delayed passage of contrast material into distal stomach (ds). Note esophageal reflux (er). Esophagogastroduodenoscopy confirmed findings, and uncomplicated stomal balloon dilatation and band volume adjustment were performed.

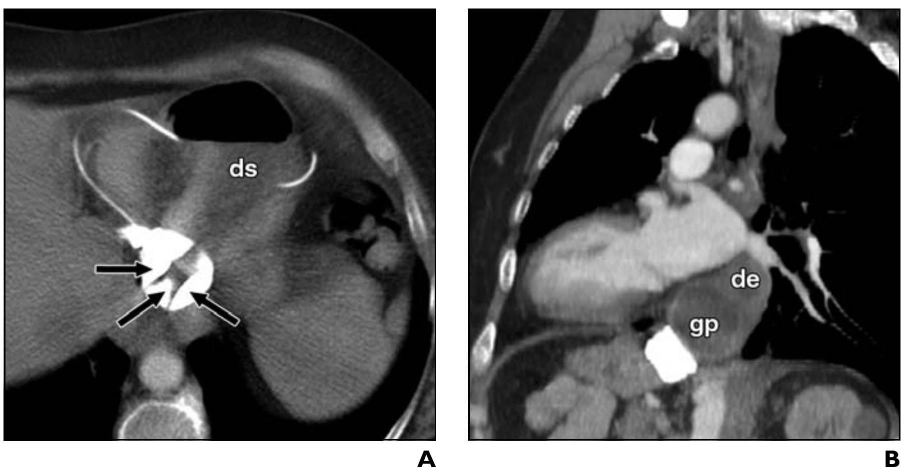


Fig. 18—70-year-old man with stomal stenosis secondary to overinflation of laparoscopic adjustable gastric banding.
A and **B,** Axial (**A**) and right anterior oblique slab reformatted (**B**) CT images show bulging band balloon (*arrows,* **A**) filled with radiopaque contrast material, distal stomach (ds), dilated gastric pouch (gp), and dilated distal esophagus (de). Band used was Swedish adjustable gastric band (SAG-BAND, Ethicon Endo-Surgery).

Laparoscopic Adjustable Gastric Banding

Laparoscopic adjustable gastric banding is associated with complications both similar to and distinct from those with a Roux-en-Y gastric bypass [56, 57]. In addition, complications can arise related to malfunctions of the implanted subcutaneous port, which have a reported incidence of approximately 1.2–5% [58–60]. Table 3 outlines the complications of laparoscopic adjustable gastric banding.

Postoperative infection—Postoperative infection may manifest as superficial cellulitis or as intraabdominal abscess, despite the use of a sterile technique. When the infection is diagnosed early, IV antibiotics usually suffice. With delayed diagnosis, the infection will often require surgical débridement, reoperation, and possibly band and port removal. One patient who presented with abdominal pain and anemia developed a postoperative abscess 21 days after surgery (Fig. 17). Despite IV antibiotics and sonographically guided placement of a drainage catheter, the abscess persisted and draining trocar wounds developed. Subsequently, the gastric band and port were removed, at which time a fistulous connection was discovered connecting the subcutaneous port site and the lesser sac.

Stomal stenosis—Stenosis at the stoma created by gastric band placement is reported to occur in approximately 8–11% of patients, irrespective of cause [23, 61, 62]. Stenosis can result from a myriad of mechanisms. Gastric edema in the immediate postoperative period is probably the most common cause; it resolves spontaneously. The gastric band is typically not inflated at surgery to circumvent exacerbation of stenosis caused by postoperative edema. Gastric inflammation with mucosal thickening can cause stenosis at any time [63]. In addition, stomal stenosis is also seen with iatrogenic overinflation (Fig. 18) of the band or as a result of hyperosmolar contrast injection into the band [64, 65]. Depending on the degree of stenosis, fluoroscopic findings will vary from delayed transit of contrast material from a relatively normal-size gastric pouch (Fig. 19) to frank obstruction with gastric pouch enlargement and esophageal reflux.

Even with proper band placement, herniation of the distal stomach wall may occur. Termed "band slippage," herniation can occur posteriorly or anteriorly. Posterior herniation of the distal stomach superiorly through the band results in stenosis and lateral eccentric gastric pouch enlargement, a phi angle greater than 58°, and possible obstruction [66] (Fig. 20). On the other hand, anterior herniation results in stenosis with medial eccentric gastric pouch enlargement and a phi angle less than 4° [24]. Mild to moderate band slippage without obstruction can often be managed nonsurgically

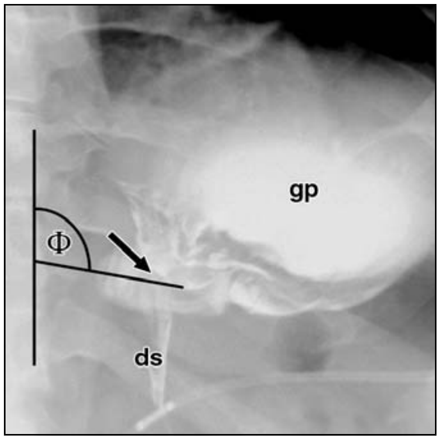


Fig. 20—32-year-old man with stomal stenosis secondary to posterior band slippage 1 week after laparoscopic adjustable gastric banding .Fluoroscopic spot image shows air–contrast level in distended lateral eccentric gastric pouch (gp), severely narrowed stoma (*arrow*), and minimal contrast material distal to band. Phi angle (Φ) is greater than 90°. Diagnostic laparotomy confirmed findings. Band and port were removed and anterior gastric wedge resection was performed because of necrosis beneath band. ds = distal stomach.

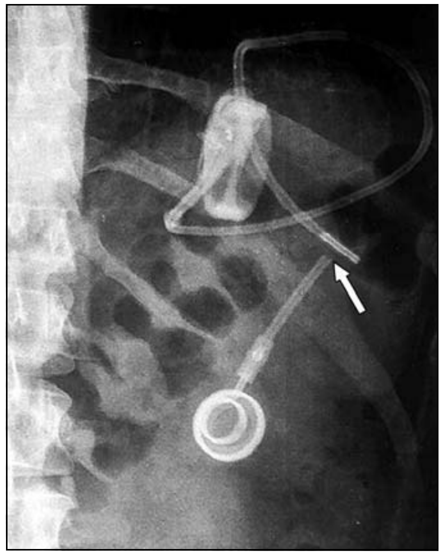


Fig. 21—Patient with disconnected connection tubing after laparoscopic adjustable gastric banding. Anteroposterior fluoroscopic image shows disconnection of gastric banding system (*arrow*) after blunt trauma. (Reprinted from Wiesner W, Schob O, Hauser RS, Hauser M. Adjustable laparoscopic gastric banding in patients with morbid obesity: radiographic management, results, and postoperative complications. *Radiology* 2000; 21:389–394 [64])

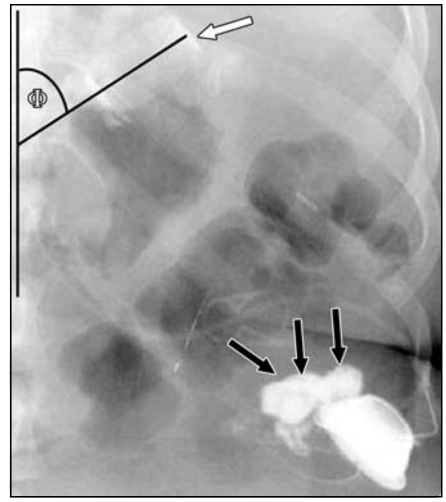


Fig. 22—Anteroposterior overhead image after injection of contrast material into port in patient with connection tubing leak after laparoscopic adjustable gastric banding. Note leak of contrast material at junction of port and connector tube (*black arrows*) and band in normal position (*white arrow*). Φ = phi angle. (Reprinted from Mehanna MJ, Birjawi G, Moukaddam HA, Khoury G, Hussein M, Al-Kutoubi A. Complications of gastric banding: a radiological pictorial review. *AJR* 2006; 186:522–534 [24])

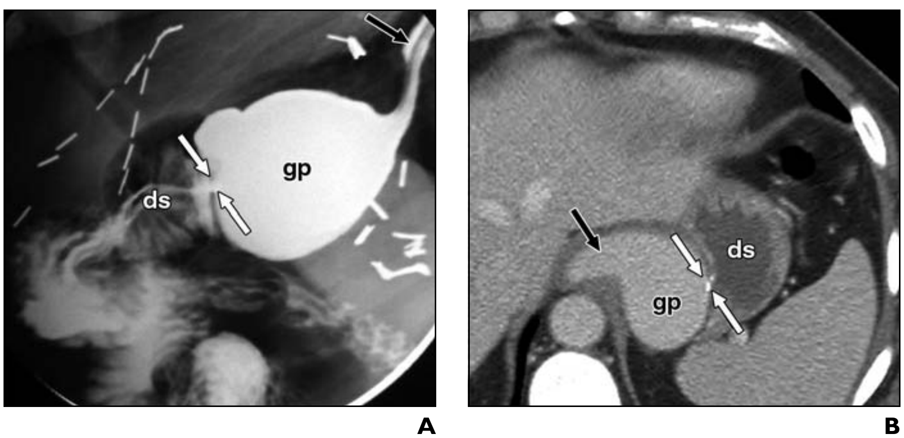


Fig. 23—51-year-old woman with vomiting secondary to severe gastric stomal stenosis 4 months after vertical-banded gastroplasty.
A and **B,** Oblique fluoroscopic spot (**A**) and axial CT (**B**) images show enlarged gastric pouch (gp), distal stomach (ds), severe narrowing of stoma (*white arrows*), and esophageal reflux (*black arrow,* **B**).

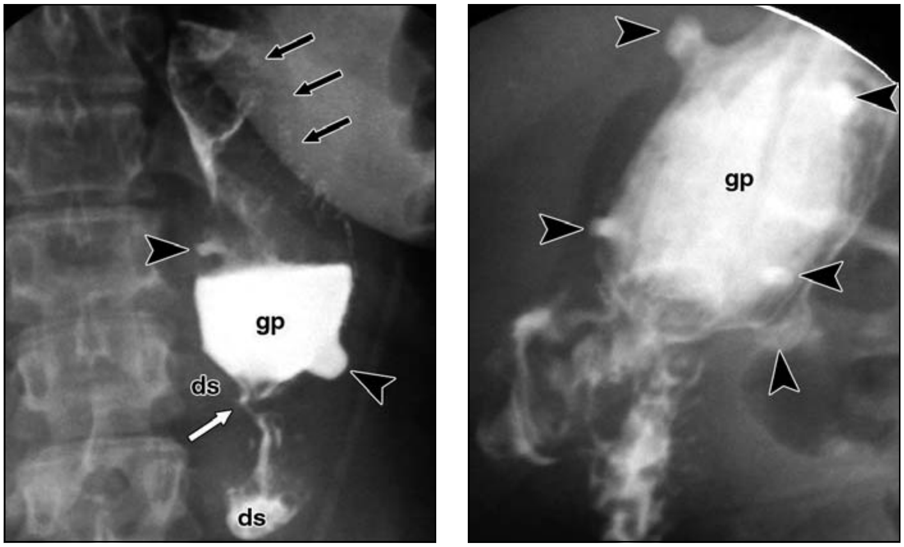
by band deflation and observation for 3–4 weeks. If the band spontaneously repositions, slow reinjection of the band can occur. However, severe slippage with obstruction must be corrected surgically to avoid potential fatal complications of gastric volvulus, infarction and necrosis, and perforation [46].

Stomal stenosis resulting in gastric pouch dilatation can be conservatively managed when it is not associated with band slippage [64]. However, when slippage is present, surgical correction is warranted to prevent potentially fatal consequences such as gastric volvulus, gastric infarction and necrosis, and gastric perforation [46].

Band system leakage—Leakage can occur at the level of the band, the connector tubing, or the access port. Leak should be suspected when insufficient deflation volume and loss of eating restriction are discovered. Causes of leak include trauma (Fig. 21), repositioning of the port, iatrogenic causes, or a defective device. Typically, leak is detected when adjusting band diameter under fluoroscopy [23] (Fig. 22). A ^{99m}Tc-albumin study can help locate the leak in equivocal cases [67].

Vertical-Banded Gastroplasty

VBG has fallen into disfavor among surgeons because of complications that include



A B

Fig. 24—39-year-old woman with gastric stomal stenosis and gastric diverticula 15 years after vertical-banded gastroplasty.
A and **B,** Fluoroscopic spot images show delayed passage of contrast material into distal stomach (ds) and gastric pouch (gp) enlargement with air–contrast level. Note narrowed gastric stoma (*white arrow*), gastric pouch diverticula (*arrowheads*), and staple line (*black arrows*). Esophagogastroduodenoscopy confirmed findings and showed long-segment Barrett's esophagus. Uncomplicated gastric stoma balloon dilatation to 15 mm was performed.

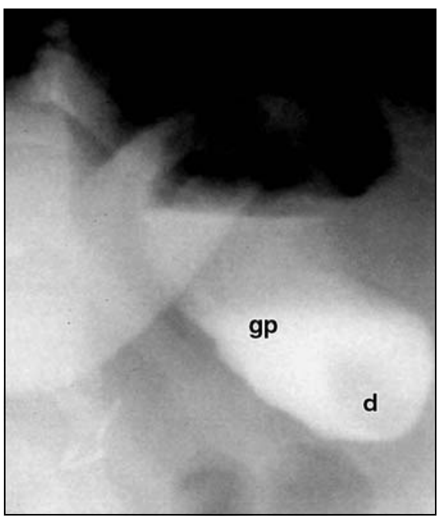


Fig. 25—37-year-old woman with complete gastric obstruction secondary to stomal food impaction 3 years after vertical-banded gastroplasty. Oblique fluoroscopic spot image 15 minutes after contrast administration shows gastric pouch (gp) enlargement with air–contrast level and dependent nonmobile filling defect (d). Esophagogastroduodenoscopy confirmed food lodged in stoma that was successfully removed. Stomal diameter was normal.

inferior long-term weight loss, severe gastroesophageal reflux, and failure of resolution of comorbidities. Early postsurgical complications include edematous stomal narrowing, gastric leak, abscess formation, gastric perforation secondary to ischemia or hyperacidity, and staple line disruption. Late postsurgical complications include stomal stenosis, pouch enlargement, stomal widening, staple line disruption, ulceration, and food impaction [68, 69].

Stomal stenosis—Similar to the Roux-en-Y gastric bypass, stomal stenosis is common in the early postoperative setting as a result of edema; spontaneous resolution is the norm. Stomal stenosis in the late postsurgical setting results from chronic inflammation, fibrotic changes, and, rarely, erosion of the band. Late stomal stenosis has a wide range of reported incidence, from 0.4% to 20% [62, 70, 71]. Unlike early stenosis, most cases of late stomal narrowing will require endoscopic balloon dilatation.

Fluoroscopy typically shows narrowing of the gastric stoma, delayed outflow from the gastric pouch, and varying degrees of pouch dilatation and gastroesophageal reflux (Fig. 23). A less common, and infrequently reported, finding seen with stomal stenosis is the formation of diverticula in the gastric pouch [72, 73] (Fig. 24).

Food impaction—Food impaction occurs typically when patients do not adhere to strict dietary measures. Preexisting stomal stenosis increases the risk; however, even with normal stomal diameter, food may become lodged in the stoma, resulting in partial or complete obstruction (Fig. 25).

Conclusion

Obesity is a serious worldwide health problem. As a result of failed conservative approaches and the proven effectiveness of bariatric surgical procedures, more patients are turning to surgical options in managing a potentially life-threatening illness.

The variety of bariatric surgical procedures and possible complications one may encounter emphasizes the importance of understanding postsurgical anatomy in patients undergoing radiologic evaluation. Evaluation of bariatric patients may not be routine and may present a perplexing diagnostic challenge. Having practical knowledge of postsurgical anatomy enables accurate interpretation of imaging findings related to normal postsurgical anatomy and common postsurgical complications.

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