Radiology

Imaging of Bariatric Surgery: Normal Anatomy and Postoperative Complications[1]

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Obesity is a disease that has reached epidemic proportions in the United States and around the world. During the past 2 decades, bariatric surgery has become an increasingly popular form of treatment for morbid obesity. The most common bariatric procedures performed include laparoscopic Roux-en-Y gastric bypass, laparoscopic adjustable gastric banding, and laparoscopic sleeve gastrectomy. Fluoroscopic upper gastrointestinal examinations and abdominal computed tomography (CT) are the major imaging tests used to evaluate patients after these various forms of bariatric surgery. The purpose of this article is to present the surgical anatomy and normal imaging findings and postoperative complications for these bariatric procedures at fluoroscopic examinations and CT. Complications after Roux-en-Y gastric bypass include anastomotic leaks and strictures, marginal ulcers, jejunal ischemia, small bowel obstruction, internal hernias, intussusception, and recurrent weight gain. Complications after laparoscopic adjustable gastric banding include stomal stenosis, malpositioned bands, pouch dilation, band slippage, perforation, gastric volvulus, intraluminal band erosion, and port- and band-related problems. Finally, complications after sleeve gastrectomy include postoperative leaks and strictures, gastric dilation, and gastroesophageal reflux. The imaging features of these various complications of bariatric surgery are discussed and illustrated.

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Learning Objectives:

After reading the article and taking the test, the reader will be able to:

- Describe the surgical anatomy and normal imaging findings for three major forms of bariatric surgery, including Roux-en-Y gastric bypass, laparoscopic adjustable gastric banding, and laparoscopic sleeve gastrectomy.
- Identify the major complications of these three forms of bariatric surgery and their relevant clinical features.
- Assess the imaging findings of fluoroscopic upper gastrointestinal examinations and CT for the complications associated with these three forms of bariatric surgery.

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Obesity has become a disease of epidemic proportions in the United States and around the world. In 2004, the U.S. Centers for Disease Control and Prevention reported that 66% of American adults were overweight and 32% suffered from obesity (1). It is the second leading cause of preventable death in the United States (after tobacco use), with more than 300 000 deaths annually (2). This epidemic also has enormous financial implications for the United States, with obesity accounting for more than 20% of all national health expenditures (3).

Essentials

- Radiologists should be familiar with the surgical anatomy and normal imaging findings for major bariatric procedures, including Roux-en-Y gastric bypass, laparoscopic adjustable gastric banding, and laparoscopic sleeve gastrectomy.
- Fluoroscopic upper gastrointestinal (GI) examinations with water-soluble contrast agents and abdominal CT are useful imaging tests for detecting leaks after Roux-en-Y gastric bypass; upper GI barium studies are better for detecting anastomotic strictures, whereas CT optimizes detection of small bowel obstructions, internal hernias, and intussusceptions.
- Upper GI barium studies are useful for showing postoperative complications such as stomal stenosis, band slippage, and gastric volvulus after laparoscopic adjustable gastric banding, and for assessing routine band adjustments.
- Fluoroscopic upper GI examinations with water-soluble contrast agents and CT are useful imaging tests for detecting leaks after sleeve gastrectomy, and barium studies are also useful for showing strictures or gastric outlet obstruction as a complication of this surgery.

Obesity is measured by body mass index (BMI), a value based on a combination of weight and height (BMI = weight [kilograms]/height [meters]^2). *Overweight* is defined as a BMI of 25–29 kg/m^2, *obesity* is defined as a BMI of 30–35 kg/m^2, and *morbid obesity* is defined as a BMI of greater than 35–40 kg/m^2 (4). Bariatric surgery is by far the most invasive form of therapy for obesity, so it is ideally reserved for patients who fail to lose weight with diet, exercise, and behavioral modification (5). Despite these guidelines, the use of bariatric surgery has increased dramatically, with five times as many bariatric surgical procedures performed in the United States in 2003 as in 1998 (6).

There are two surgical approaches for achieving weight loss in obese patients: bypass procedures in which portions of the gastrointestinal (GI) tract are bypassed to cause malabsorption, and restrictive procedures in which gastric volume is decreased to induce early satiety. Jejunoileal bypass procedures have been largely abandoned because of the degree of malabsorption in these patients (5). Proponents of bariatric surgery have instead advocated a variety of restrictive procedures (sometimes combined with a bypass component) to induce weight loss, including Roux-en-Y gastric bypass, laparoscopic adjustable gastric banding, and laparoscopic sleeve gastrectomy. This article reviews the most commonly performed bariatric procedures, the normal imaging findings on fluoroscopic upper GI and computed tomography (CT) studies, and the role of imaging studies in detecting complications associated with these procedures.

Laparoscopic Roux-en-Y Gastric Bypass

Laparoscopic Roux-en-Y gastric bypass is the most popular bariatric procedure performed in the United States because it is associated with greater sustained weight loss and higher long-term success rates than other forms of bariatric surgery. Surgical bypass of a variable length of small bowel is a contributing factor, but weight loss is thought to result primarily from early satiety caused by the restrictive effect of a small, surgically created gastric pouch rather than the malabsorptive effect of small bowel bypass (7).

Surgical Anatomy

Roux-en-Y gastric bypass entails the use of a stapler-cutter device to create a staple line that partitions the stomach into a small fundal component (ie, the *gastric pouch)* and a much larger excluded component (ie, the *excluded stomach*) (Fig 1). The jejunum is then divided 25–50 cm distal to the ligament of Treitz, and the distal limb (ie, the *Roux limb*, *alimentary limb*, or *efferent limb*) is brought up and anastomosed to the gastric pouch by means of an end-to-end or, more commonly, an end-to-side gastrojejunal anastomosis, creating a short, blind-ending jejunal stump (8). The gastrojejunal anastomosis can be antegastric or retrogastric in location and is deliberately fashioned as a small-caliber stoma (ranging 8–12 mm in diameter) to limit emptying of solid food from the gastric pouch and facilitate weight loss by means of a restrictive effect. The Roux limb can be brought up to the gastric pouch anterior or posterior to the transverse colon; a posterior approach necessitates creation of a small defect or window in the transverse mesocolon through which the Roux limb passes (8–10). Finally, the proximal limb of the divided jejunum (ie, the *biliopancreatic limb* or *afferent limb*) is anastomosed to the small bowel 75–150 cm distal to the gastrojejunostomy to create a common channel that continues into the ileum (8–10). The jejunojejunostomy is usually created by means of a side-to-side anastomosis to decrease the risk of stricture formation.

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Abbreviations:
GI = gastrointestinal
SBO = small bowel obstruction

Conflicts of interest are listed at the end of this article.

Figure 1

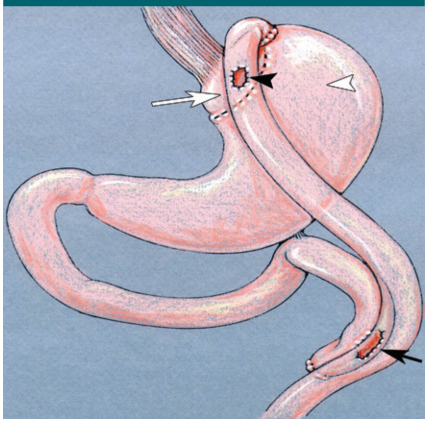


Figure 1: Diagram shows normal surgical anatomy after Roux-en-Y gastric bypass. A staple line partitions the stomach into a small fundal pouch (white arrow) and a much larger excluded stomach (white arrowhead). The jejunal Roux limb is joined proximally to the fundal pouch via a gastrojejunal anastomosis (black arrowhead) and distally to the biliopancreatic limb via a jejunojejunal anastomosis (black arrow). (Reprinted, with permission, from reference 12.)

Figure 2

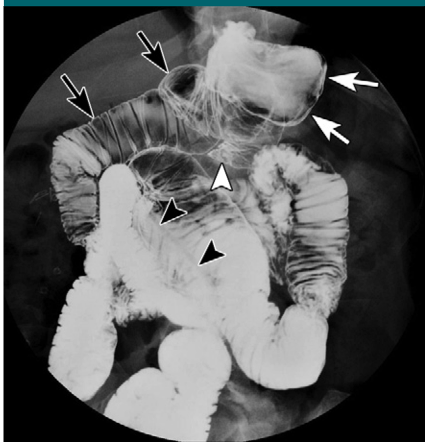


Figure 2: Normal imaging findings after Roux-en-Y gastric bypass. Supine spot image from single-contrast upper GI barium study shows opacified gastric pouch (white arrows), with barium entering Roux limb (black arrows) and blind-ending jejunal stump (white arrowhead). Note widely patent side-to-side jejunojejunostomy (black arrowheads) visualized in profile. Gaseous distention of small bowel loops resulted from aerophagia (not administration of effervescent agent).

Figure 3

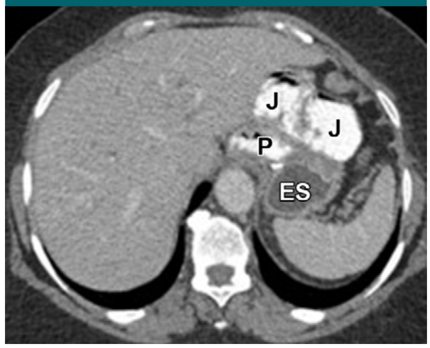


Figure 3: Normal appearance of Roux-en-Y gastric bypass at CT. Axial CT image after oral and intravenous contrast material administration shows small gastric pouch *(P)* separated by staple line from excluded stomach *(ES)* laterally. Jejunal Roux limb *(J)* is anastomosed to gastric pouch anteriorly. Note oral contrast material opacifying pouch and Roux limb, whereas excluded stomach is not opacified.

Normal Imaging Findings

Upper GI examination.—The gastric pouch typically appears on upper GI studies as a small structure with a volume of 15–20 mL, though considerable variation may be encountered. The gastrojejunal anastomosis should be visualized in profile (without overlap between the gastric pouch and jejunum) to provide a reasonable estimate of anastomotic diameter. When the jejunum is connected to the inferior aspect of the pouch, the gastrojejunal anastomosis is readily visualized on frontal views, but when the jejunum is connected to the anterior or posterior aspect of the pouch, steep oblique or lateral views may be required to visualize the anastomosis in profile (11). In the absence of obstruction, contrast material should pass freely into the Roux limb. The study is not completed until the small bowel is opacified beyond the jejunojejunostomy, so the jejunojejunal anastomosis can also be assessed (Fig 2).

When obtaining upper GI studies in patients with Roux-en-Y gastric bypass, it is important to follow the head of the column of contrast material at fluoroscopy as it passes from the esophagus into the gastric pouch and then from the pouch into the Roux limb via the gastrojejunal anastomosis. This approach facilitates detection of staple line breakdown as well as leaks or strictures at the gastrojejunal anastomosis that later may be obscured by overlying loops of opacified small bowel (12).

When the Roux limb is retrocolic, it is brought up to the gastric pouch via a surgically created window in the transverse mesocolon. As a result, there may be a short segment of circumferential narrowing of the Roux limb where it traverses this window and is sutured to the surrounding transverse mesocolon (13). This finding should not be mistaken for an ischemic stricture or other cause of jejunal narrowing.

Abdominal CT.—After gastric bypass surgery, CT examinations are ideally performed with both oral and intravenous contrast agents. Because of the size and girth of bariatric patients, it may be necessary to adjust technical factors such as kilovoltage, milliamperage, field of view, and collimation thickness (14,15). Identification of the gastric pouch, gastrojejunal anastomosis, jejunal Roux limb, jejunojejunal anastomosis, and biliopancreatic limb on CT scans is essential for detecting potential complications such as internal hernias and small bowel obstructions. Positive oral contrast material administered just prior to image acquisition helps differentiate the gastric pouch and Roux limb from the excluded stomach and biliopancreatic limb, which are not opacified (Fig 3). The volume of administered oral contrast material will depend on the patient's tolerance and symptoms. The Roux limb should be followed along its antecolic or retrocolic course to the jejunojejunal anastomosis, typically in the left midabdomen. The excluded stomach should be visualized on CT images and is normally collapsed in these patients (Fig 3) (14,16). Failure to identify the excluded stomach could result in misdiagnosis of this fluid-filled structure as an abscess. CT also enables visualization of fluid- and/or gas-filled loops of small bowel in the biliopancreatic limb, which is not generally identified on barium studies because intestinal peristalsis often prevents retrograde filling of this limb with barium.

Figure 4

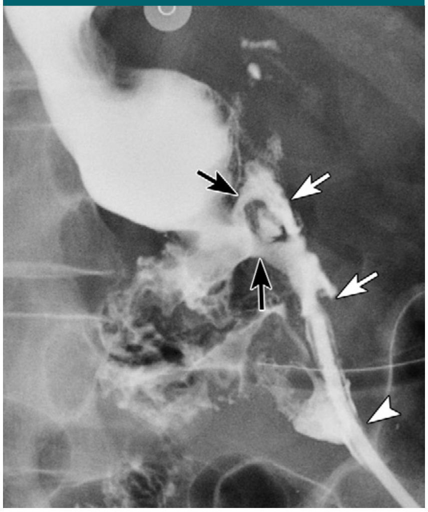


Figure 4: Roux-en-Y gastric bypass with postoperative anastomotic leak. Supine spot image from upper GI examination with water-soluble contrast material shows focal extravasation from left lateral aspect of gastrojejunal anastomosis into two short tracks (black arrows) and adjoining extraluminal collection (white arrows). Note contrast material passing through and around drain (arrowhead) that communicates with inferior aspect of this collection.

Figure 5

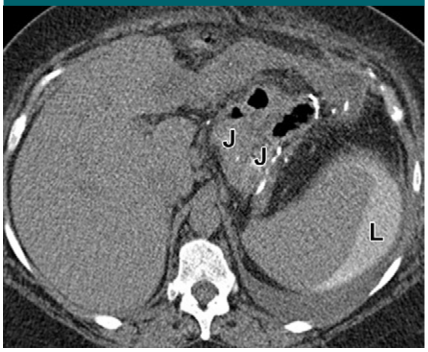


Figure 5: Roux-en-Y gastric bypass with postoperative anastomotic leak at CT after oral but not intravenous contrast material administration. Axial CT image shows extravasated contrast material in perisplenic space *(L)*, indicating a postoperative leak. Note jejunal Roux limb more medially *(J)*.

Complications

Leaks.—Extraluminal leak is the most serious early complication of Roux-en-Y gastric bypass, occurring in up to 5% of patients (12). Between 69% and 77% of leaks involve the gastrojejunal anastomosis (12,17), but other less common sites of perforation include the gastric pouch, blind-ending jejunal stump, and jejunojejunostomy (12). Leaks usually occur within 10 days of surgery; early detection is critical because of the risk of abscess formation, peritonitis, and sepsis, with a mortality rate of more than 5% (12). Affected individuals may present with leukocytosis, fever, abdominal pain, and tachycardia (12). Although one study found that a heart rate exceeding 120 beats per minute was the single most reliable sign of perforation (18), the clinical symptoms are often nonspecific, and the physical examination may be limited by the large body habitus of these patients. Because of clinical difficulties in diagnosing postoperative leaks, some authors advocate routine upper GI examinations with water-soluble contrast agents 1–2 days after surgery as the preferred imaging test for ruling out leaks after gastric bypass surgery (12,17).

When upper GI examinations are performed, scout images should be obtained to detect loculated or free extraluminal gas as well as radiopaque staple lines that otherwise could be mistaken for small leaks during the fluoroscopic examination. After water-soluble contrast material has been administered, most leaks from the gastrojejunal anastomosis are best visualized with the patient in a supine or supine left posterior oblique position, appearing as blind-ending tracks or sealed-off collections abutting the anastomotic region (Fig 4) or, less frequently, as free leaks into the peritoneal cavity (12). About 75% of these leaks extend to the left of the gastrojejunal anastomosis as extraluminal collections in the left upper quadrant on upper GI studies or CT scans, sometimes continuing superiorly into the subphrenic space (Fig 5) (12). Subtle leaks may only be recognized indirectly by contrast material entering a surgical drain near the gastrojejunal anastomosis. If no leak is detected with a water-soluble contrast agent, high-density barium should be administered to demonstrate subtle leaks that might otherwise be missed (19). Less commonly, leaks may be detected from the blind-ending jejunal stump or jejunojejunostomy (12).

Most patients with anastomotic leaks require repeat surgery, but small sealed-off leaks may be successfully treated with percutaneous drainage catheters and antibiotics. Whatever the site of origin, an extraluminal leak should be differentiated from breakdown of a gastric staple line and the development of a so-called *gastrogastric fistula* that has very different implications for patient management (see later section on recurrent weight gain).

Anastomotic narrowing and strictures.—Transient anastomotic narrowing and obstruction may occur during the early postoperative period secondary to residual edema and spasm in this region (8). Upper GI examinations may reveal focal narrowing of the gastrojejunal anastomosis and thickened, irregular folds in the Roux limb abutting the anastomosis. These findings usually resolve within several days.

Strictures at the gastrojejunal anastomosis have been reported in 3%–9% of patients (20). These strictures typically develop 4 weeks or more after surgery; they may be caused by postsurgical scarring at the anastomosis or by chronic ischemia resulting from tension on the gastrojejunostomy (21). Affected individuals usually present with postprandial vomiting, bloating, and upper abdominal pain, sometimes associated with rapid weight loss. Obstructive symptoms from strictures at the gastrojejunal anastomosis tend to develop shortly after meals, whereas vomiting associated with small bowel adhesions, internal hernias, or strictures at the jejunojejunal anastomosis may occur 1 hour or more later.

Anastomotic strictures usually appear on upper GI studies as short segments of smooth narrowing at the gastrojejunal anastomosis (Fig 6) (18). If obstruction is present, the gastric pouch may be dilated, and emptying of barium into the Roux limb may be delayed. Strictures at anastomoses that have an inferior location in relation to the gastric pouch are readily detected with patients in the frontal position, whereas strictures at anastomoses that have an anterior or posterior location

Figure 6

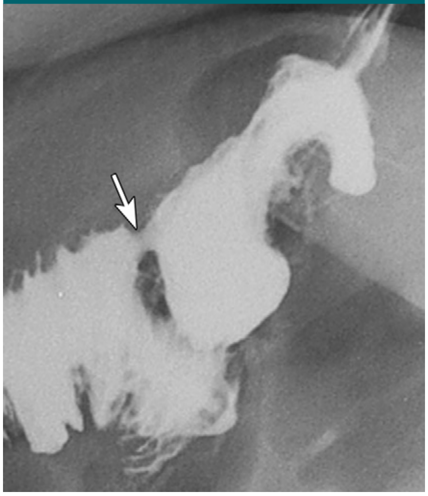


Figure 6: Roux-en-Y gastric bypass with anastomotic stricture. Steep right posterior oblique spot image from single-contrast upper GI barium study shows gastrojejunal anastomosis in profile, enabling visualization of a tight anastomotic stricture (arrow). This stricture was not visible on supine spot images because of overlap between lower end of gastric pouch and upper end of jejunal Roux limb that obscured anastomotic region.

Figure 7

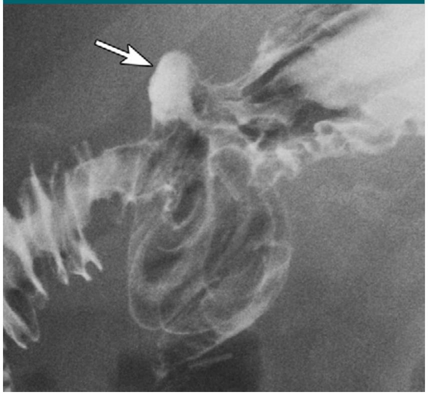


Figure 7: Roux-en-Y gastric bypass with marginal ulcer. Supine right posterior oblique spot image from single-contrast upper GI barium study shows discrete ulcer niche (arrow) in jejunal Roux limb abutting gastrojejunal anastomosis. This patient presented with abdominal pain and melena.

Figure 8

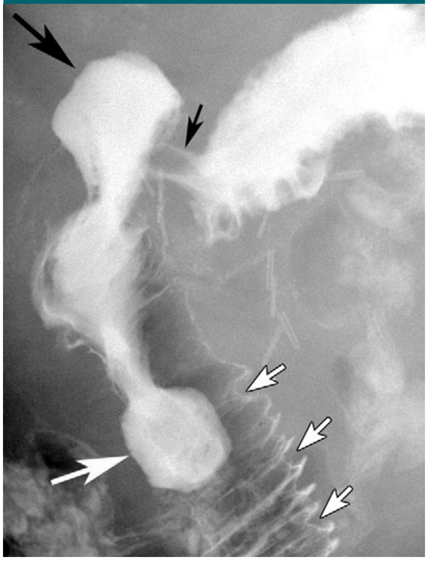


Figure 8: Roux-en-Y gastric bypass with giant jejunal ulcers. Supine right posterior oblique spot image from single-contrast upper GI barium study shows giant ulcer (large black arrow) in jejunal Roux limb abutting gastrojejunal anastomosis (small black arrow) and second giant ulcer (large white arrow) more distally in Roux limb. Note thickened, spiculated folds (small white arrows) in adjacent small bowel. (Reprinted, with permission, from reference 28.)

can be missed on frontal views because of overlap between the pouch and Roux limb that obscures the anastomosis (11). As a result, steep oblique or lateral views may be required to visualize these strictures by eliminating overlap and showing the anastomosis in profile (Fig 6) (11). Patients with anastomotic strictures often have an excellent response to endoscopic dilation of the strictures (22), but some patients may require multiple dilation procedure.

Marginal ulcers.—Ulcers at the gastrojejunal anastomosis (ie, *marginal ulcers*) have been reported in 3%–13% of patients after Roux-en-Y gastric bypass (23–25). It has been postulated that these ulcers develop as a result of chronic exposure of the mucosa to acid entering the Roux limb (24). Affected individuals typically present with epigastric pain or upper GI bleeding. Marginal ulcers are manifested on barium studies as discrete ulcer niches at the gastrojejunal anastomosis or, even more commonly, in the Roux limb abutting the anastomosis (Fig 7) (26). They usually occur as solitary ulcers of varying size. Most marginal ulcers respond to medical therapy with antisecretory agents (ie, proton pump inhibitors) (26), though surgical revision of the gastrojejunal anastomosis occasionally may be required for intractable ulcers (24).

Jejunal ischemia.—Some patients develop acute ischemia of the Roux limb because of tension on the surgically mobilized jejunum that compromises its vascular supply (21). Affected individuals typically present with severe abdominal pain, upper GI bleeding, or nausea and vomiting during the early postoperative period (27). Barium studies may reveal thickened, spiculated folds or thumb printing secondary to submucosal edema and hemorrhage, and CT may reveal a thickened jejunal wall in the ischemic segment, with edema of the mesentery and engorged mesenteric vessels. Mild jejunal ischemia is often self-limited, but more severe ischemia can lead to small bowel infarction.

In contrast, chronic ischemia of the Roux limb may cause intractable nausea and vomiting secondary to the development of a jejunal stricture (27). Barium studies may reveal a segment of tubular narrowing that has a smooth contour, tapered margins, and effaced or obliterated folds (27). CT may also reveal a long segment of jejunal narrowing with bowel wall thickening and mural stratification (ie, a *target sign*). In some patients, surgical resection of the ischemic segment is required for treatment of obstruction (27).

Other patients with chronic jejunal ischemia may develop one or more giant (ie, 2.5 cm or larger) ulcers in the Roux limb abutting the gastrojejunal anastomosis or at a discrete distance from the anastomosis (Fig 8) (27,28). These individuals are more likely to require resection of the diseased jejunum and revision of the anastomosis than other patients with marginal ulcers (28). The presence of one or more giant, nonhealing ulcers in the Roux limb after gastric bypass surgery should therefore suggest chronic jejunal ischemia and the need for aggressive medical or even surgical management of these patients.

Figure 9

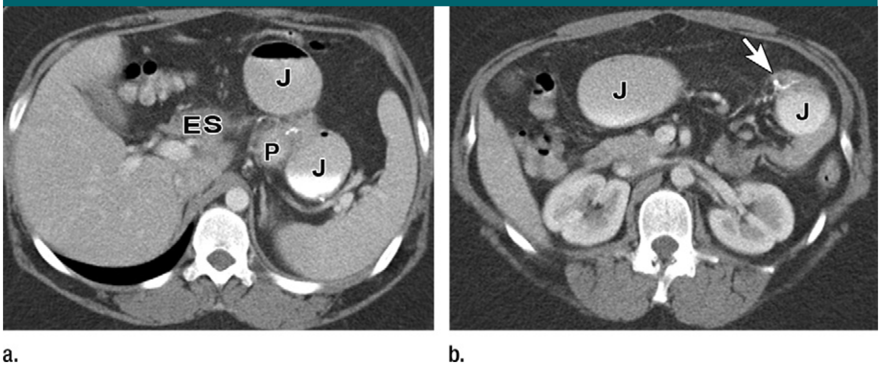


Figure 9: Roux-en-Y gastric bypass with obstruction of jejunal Roux limb at CT. **(a, b)** Axial CT images after oral and intravenous contrast material administration show dilated gastric pouch *(P)* and jejunal Roux limb *(J)* extending into left midabdomen, with abrupt transition due to obstruction at jejunojejunal anastomosis (arrow). The excluded stomach *(ES)* is decompressed.

Figure 10

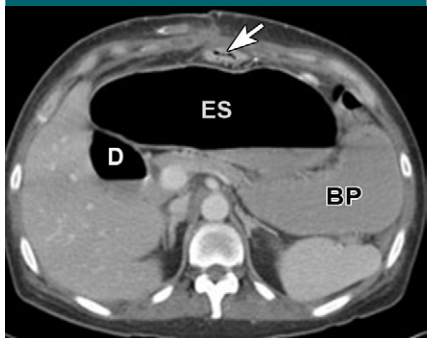


Figure 10: Roux-en-Y gastric bypass with obstruction of biliopancreatic limb. Axial CT image after oral and intravenous contrast material administration shows a dilated, gas- and fluid-containing excluded stomach *(ES)*, duodenum *(D)*, and biliopancreatic limb *(BP)*. The excluded stomach should be collapsed after Roux-en-Y gastric bypass. Recognition of surgical anatomy and collapsed jejunal Roux limb (arrow) is essential for establishing the diagnosis of this closed-loop obstruction.

Small bowel obstruction.—Small bowel obstruction (SBO), which occurs in up to 5% of patients, may be caused by adhesions, internal hernias, anterior abdominal wall hernias, strictures at the jejunojejunal anastomosis, and, rarely, intussusceptions (29–31). An ABC classification system has been devised for three different types of SBO seen on barium studies and CT scans after Roux-en-Y gastric bypass based on the location of alterations to the GI tract relative to the jejunojejunal anastomosis (32,33), as follows:

A: Type A is SBO with a dilated alimentary limb (Roux limb) and decompressed biliopancreatic limb. This type is manifested on barium studies by a dilated Roux limb obstructed at or above the jejunojejunostomy (Fig 9). Recognition of the dilated Roux limb and collapsed excluded stomach and duodenum may be difficult on CT studies.

B: Type B is SBO with a dilated biliopancreatic limb. This type is a closed-loop obstruction that causes marked distention of the excluded stomach and biliopancreatic limb at or above the jejunojejunostomy. Affected individuals are at high risk for perforation unless prompt therapy is instituted. Because the biliopancreatic limb and excluded stomach are not usually opacified on barium studies, the diagnosis is more likely to be made at CT by visualization of a dilated, fluid-filled excluded stomach and biliopancreatic limb with a collapsed Roux limb (Fig 10). These findings should be highly suggestive of a closed-loop obstruction.

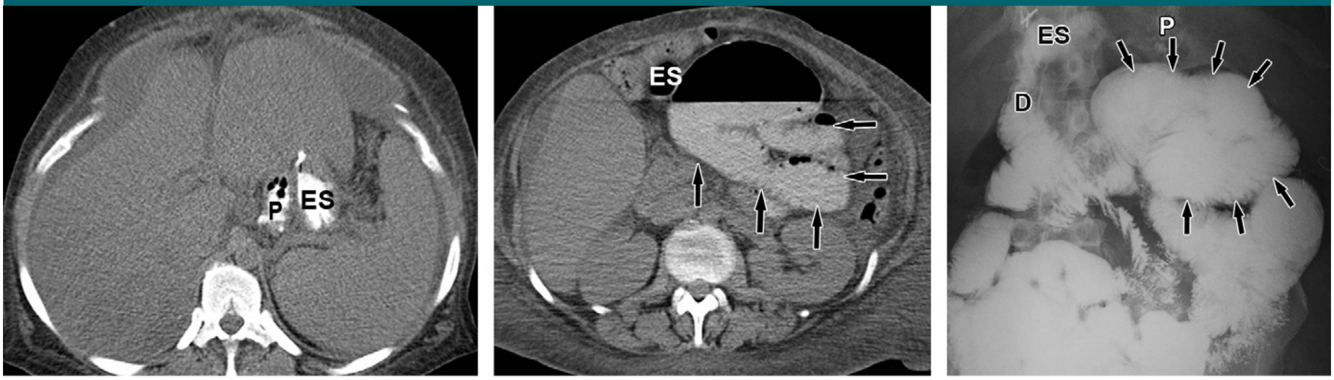
C: Type C is SBO at the level of the common small bowel channel distal to the jejunojejunostomy, with dilation of the Roux limb and biliopancreatic limb above the jejunojejunal anastomosis.

Internal hernias.—Though adhesions are the most common cause of SBO after open Roux-en-Y gastric bypass, internal hernias are the most common cause after the laparoscopic form of surgery (29–31). The low frequency of adhesions with laparoscopic technique enables the small bowel to retain its mobility, increasing the susceptibility to internal hernias (34,35). This complication of Roux-en-Y gastric bypass develops in about 3% of patients, typically occurring as a late finding (35).

Internal hernias after Roux-en-Y gastric bypass usually result from herniation of small bowel loops through a defect in the transverse mesocolon (for a retrocolic Roux limb), a defect in the small bowel mesentery (for a jejunojejunal anastomosis), or a defect posterior to the Roux limb (ie, Petersen defect). Incarceration of small bowel in an internal hernia can lead to obstruction, infarction, and perforation of strangulated loops. As a result, internal hernias can be fatal if diagnosis and treatment of this complication are delayed. A high index of suspicion is particularly important because the clinical findings are often nonspecific (31,34,35).

The diagnosis of internal hernias on imaging studies requires knowledge of the postoperative anatomy and recognition of changes in the configuration of the bowel. Small bowel loops may be clustered together in abnormal locations on barium studies and CT images, often displacing other bowel and associated with migration of an anastomotic jejunojejunal suture line. This suture line is most often displaced from its typical location in the left midabdomen into the left upper quadrant, but it can also be displaced into the right midabdomen (31). A focal cluster of small bowel loops is most often seen in the left midabdomen (90%), but clustered bowel can be located anywhere in the abdomen and pelvis (31). Barium studies may also reveal small bowel limbs entering and exiting the hernia with retention of barium within these loops (14,31). One advantage of the barium study over CT is the ability to visualize changes in the configuration of the small bowel during the course of the examination. The diagnosis of an internal hernia should be suspected on CT images when a cluster of small bowel

Figure 11



a. b. c.

Figure 11: Roux-en-Y gastric bypass with obstructing internal hernia. **(a, b)** Axial CT images after oral but not intravenous contrast material administration show a collapsed gastric pouch *(P)* and excluded stomach *(ES)*. Note dilated, clustered small bowel loops displaced into left upper quadrant (arrows) with resulting SBO. **(c)** Overhead radiograph from small bowel follow-through in same patient also shows clustered, dilated, and displaced small bowel loops in left upper quadrant (arrows), displacing other bowel. The excluded stomach *(ES)* and duodenum *(D)* are opacified as a result of retrograde flow of barium via jejunojejunostomy. This patient had a surgically proved transmesocolic internal hernia.

loops is seen in an atypical location, especially the left upper quadrant above the transverse mesocolon (Fig 11). CT also enables visualization of changes in the mesentery, such as stretching and swirling of vessels and mesenteric engorgement (31,36–38).

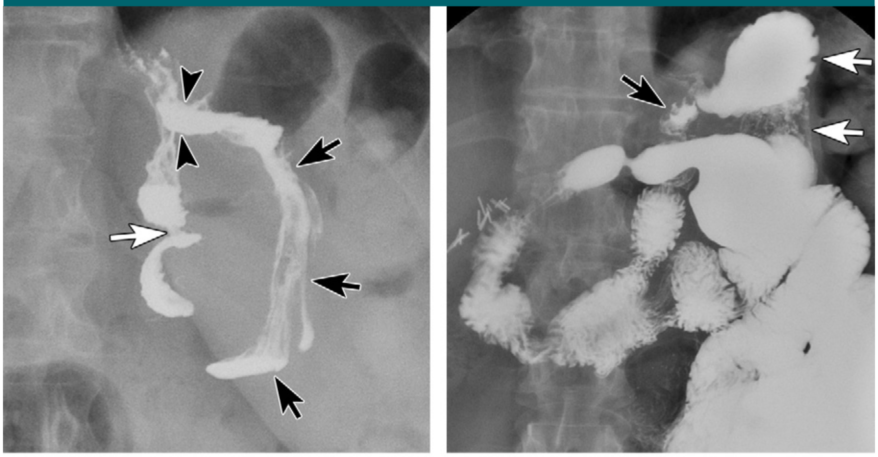
Intussusception.—Small bowel intussusceptions typically occur at or near the jejunojejunal anastomosis, with the staple line at this anastomosis presumably acting as the lead point for the intussusception. Altered small bowel motility near the anastomosis may also be a contributing factor. These intussusceptions may be transient or fixed and are a rare cause of SBO after gastric bypass surgery (39).

Recurrent weight gain.—The primary mechanism for weight loss after Roux-en-Y gastric bypass is the restrictive effect created by a small gastric pouch, causing early satiety after ingestion of even small quantities of solid food (7). As a result, one of the major causes of recurrent weight gain is partial or complete breakdown of the gastric staple line that enables food to enter the excluded stomach, eliminating the restrictive effect of the pouch. Affected individuals become aware that they have lost the sensation of early satiety created by their surgery. In effect, these patients have a *gastrogastric fistula* because their staple line dehiscence has restored communication between the gastric pouch and the excluded stomach. When there is complete surgical transection of the pouch and separation from the remaining stomach, communication between the pouch and the excluded stomach results from the development of a leak with subsequent fistula formation (40).

Upper GI studies may be performed to determine whether staple line breakdown is responsible for recurrent weight gain. The fluoroscopist should carefully assess the head of the barium column with the patient in an upright or semi-upright position to ascertain whether barium has emptied from the gastric pouch via the gastrojejunal anastomosis or whether it has traversed a dehisced portion of the staple line to enter the excluded stomach (Fig 12a). Later in the study or on overhead radiographs, barium may reflux into the biliopancreatic limb and excluded stomach, so it becomes far more difficult to assess whether the staple line is disrupted (Fig 12b). Staple line breakdown should also be suspected on CT studies when contrast material is visualized in the excluded stomach in the absence of opacification of the biliopancreatic limb and duodenum (Fig 13). If there is opacification of the biliopancreatic limb and duodenum, however, a barium study may be required to differentiate staple line breakdown from retrograde filling of the excluded stomach via the biliopancreatic limb (14,16,40).

Breakdown of the gastric staple line with a leak into the excluded stomach has been reported in about 3.5% of patients, occurring with equal frequency during the early and late postoperative periods (40). Early leaks into the excluded stomach are associated with extraluminal leaks in nearly 90% of patients (40) and may undergo spontaneous healing, so additional surgery is not always required. In contrast, leaks into the excluded stomach during the late postoperative period are more likely to be associated with recurrent weight gain and less likely to undergo spontaneous healing (40). In the past, it has been suggested that small leaks into the excluded stomach are of little clinical importance and that only large leaks are likely to cause recurrent weight gain because of rapid emptying of the gastric pouch (41). However, others have found that even small leaks into the excluded stomach may be associated with recurrent weight gain, necessitating surgical revision (40).

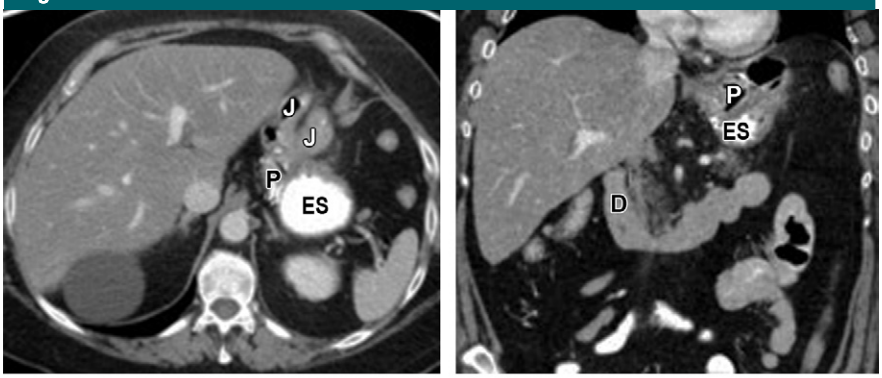
Figure 12



a. b.

Figure 12: Roux-en-Y gastric bypass with breakdown of staple line. **(a)** Supine spot image from single-contrast upper GI barium study shows focal disruption of proximal end of staple line, with barium passing from gastric pouch laterally into excluded stomach (black arrows) via gastrogastric fistula (arrowheads). (White arrow = gastrojejunal anastomosis.) **(b)** Subsequent supine spot image from same study shows extensive filling of jejunal Roux limb, with barium also opacifying biliopancreatic limb and excluded stomach (white arrows) secondary to retrograde filling via jejunojejunal anastomosis. As a result, it is difficult to differentiate staple line disruption from retrograde filling of excluded stomach on this image. (Black arrow = barium in gastric pouch.)

Figure 13



a. b.

Figure 13: Roux-en-Y gastric bypass with staple line breakdown diagnosed at CT. **(a)** Axial and **(b)** coronal CT images after oral and intravenous contrast material administration show contrast material opacifying gastric pouch *(P)* and excluded stomach *(ES)* without opacification of duodenum *(D)*, findings highly suggestive of staple line breakdown. When contrast material is also identified in duodenum and biliopancreatic limb, however, a barium study may be required to differentiate staple line disruption from retrograde filling of excluded stomach (*J* = jejunal Roux limb).

Recurrent weight gain may also result from widening of the gastrojejunal anastomosis with rapid emptying of the gastric pouch, so even a small pouch may no longer produce early satiety if there is a widened anastomosis, leading to recurrent weight gain. The diameter of the gastrojejunal anastomosis should therefore be assessed when evaluating patients for recurrent weight gain after gastric bypass surgery.

Laparoscopic Adjustable Gastric Banding

Since its introduction by Belachew et al in 1993 (42) and its approval for use in the United States in 2001 (43), laparoscopic adjustable gastric banding has become an increasingly popular form of restrictive surgery for morbid obesity. Gastric banding is a less invasive procedure than Roux-en-Y gastric bypass that produces comparable short-term weight loss with fewer complications (44,45). The band is placed around the proximal stomach (creating a small gastric pouch), and saline is intermittently administered into or withdrawn from the band to increase or decrease its restrictive effect on the stomach. Unlike other forms of bariatric surgery, this procedure therefore requires periodic adjustment of the band stoma. Stomal adjustments should ideally be made on the basis of the patient's weight loss curve and symptoms.

Surgical Anatomy

An adjustable silicone gastric band is placed around the stomach about 2 cm below the gastroesophageal junction to create a small gastric pouch above the band (Fig 14) (9,10,46,47). The band is sutured to the adjacent wall of the stomach to decrease the chances of band slippage (10). The band has an inflatable inner sleeve that is connected via tubing to a subcutaneous port in the right or, less commonly, left abdominal wall. This configuration enables adjustment of the band by altering the amount of fluid within the band via a needle inserted into the subcutaneous port. Periodic adjustment of the band is performed by administering small volumes of saline into the band in an incremental fashion to gradually tighten the band and increase its restrictive effect, promoting weight loss. Conversely, saline can be removed from the band if the patient experiences obstructive symptoms because the band is too tight.

Normal Imaging Features

Upper GI examination.—After placement of the gastric band, an upper GI examination may be performed with an

Figure 14

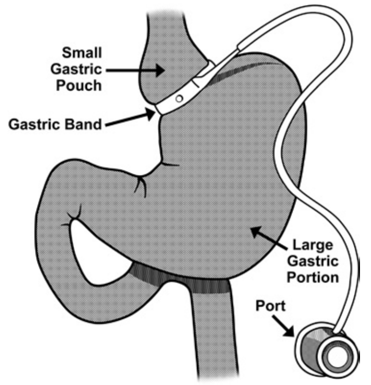
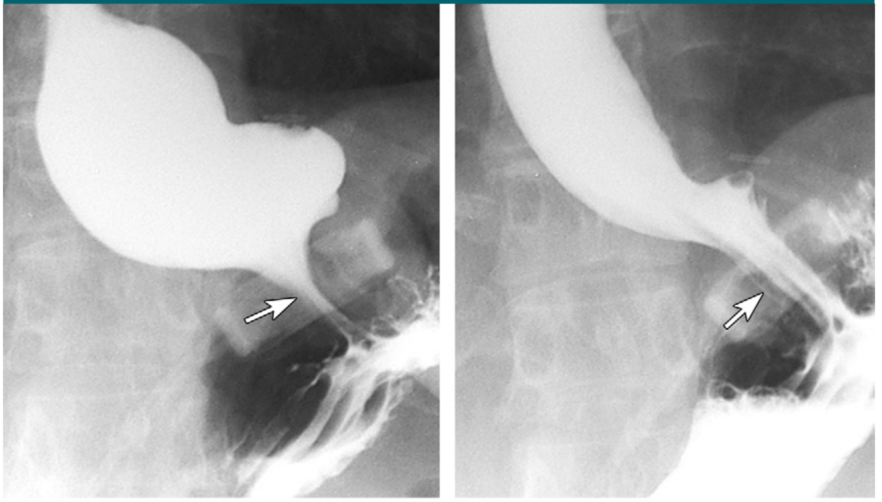


Figure 14: Diagram shows laparoscopic adjustable gastric band surrounding proximal stomach, producing a small gastric pouch above band. When saline is introduced into band via subcutaneous port, luminal narrowing causes early satiety and weight loss. (Reprinted, with permission, from reference 51.)

Figure 15



a. b.

Figure 15: Utility of routine barium study after gastric band adjustment to assess caliber of lumen where it traverses band. **(a)** Initial single-contrast upper GI barium study after administration of 2 mL of saline via subcutaneous port into band shows marked narrowing of lumen (arrow) traversing band with proximal dilation. **(b)** Repeat study after removal of 1 mL of saline shows only mild narrowing of lumen (arrow) with normal-caliber esophagus above band. On both studies, note normal position of band beneath medial aspect of left hemidiaphragm and oblique orientation with lateral edge superior to medial edge.

Figure 16

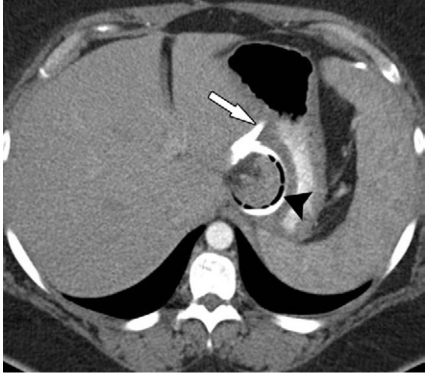


Figure 16: Expected appearance of laparoscopic gastric band at CT. Axial CT image after oral and intravenous contrast material administration shows band device (arrowhead) positioned around proximal stomach. The band is connected via tubing (arrow) to an injectable port (not see on this image) along anterior rectus sheath.

orally administered water-soluble contrast agent to confirm the location of the band in relation to the stomach, assess the caliber of the lumen through the band, and evaluate for postoperative leaks. A scout image should be obtained to document the location of the band, which normally has an oblique orientation with its lateral side above its medial side just beneath the medial aspect of the left hemidiaphragm. The angle formed by intersecting lines through the spinal column and horizontal axis of the band (ie, the *phi angle*) has a normal range between 4° and 58° (47). The band is connected by contiguous tubing to the subcutaneous port.

Administration of contrast material typically reveals a small gastric pouch above the band with tapered narrowing of the lumen where it traverses the band stoma and free passage of contrast material into the larger portion of the stomach below the band (Fig 15b). It is important to place the patient in a frontal or slightly right posterior oblique position at fluoroscopy, so the stoma can be assessed in profile without being obscured by the opacified fundus (17,41). The normal diameter of the gastric pouch is usually about 4 cm, corresponding to a volume of 15–20 mL (10).

Abdominal CT.—CT is ideally performed with both positive oral and intravenous contrast material. CT technical factors may be adjusted to accommodate for the patient's large body habitus (15). Coronal, sagittal, and oblique multiplanar reformatted images are beneficial for evaluating the gastric pouch and band. The anterior abdominal wall should be included in the field of view to assess the soft tissues surrounding the subcutaneous port.

The radiopaque band can be identified around the proximal stomach on CT images (Fig 16), and the attached tubing can be seen extending through the peritoneal space and rectus muscles before connecting to the subcutaneous port along the anterior rectus sheath. All components of the device and adjacent soft tissues should be assessed. CT may be helpful in evaluating for a source of infection and in assessing soft tissue changes related to the tubing and reservoir (17,48).

Complications

Stomal stenosis.—The most common complication after gastric banding is stomal stenosis (46). This complication occurs when the band is too tight, causing excessive luminal narrowing and obstruction. Affected individuals usually present with nausea and vomiting, regurgitation, dysphagia, or upper abdominal pain. Barium studies may reveal excessive narrowing of the lumen where it traverses the band, with dilation of the proximal stomach, pouch-esophageal reflux, and slow emptying of barium through the band into the remaining stomach (Fig 15a) (46). In extreme cases, there may be high-grade luminal obstruction by the band. If stomal stenosis causes a food impaction above the band, the patient may present with abrupt onset of severe vomiting and regurgitation and an inability to tolerate solids or even liquids by mouth. In such cases, the impacted food may be recognized on barium studies as a radiolucent defect above the band.

When stomal stenosis is found on barium studies in patients with obstructive symptoms, the band should be deflated to increase luminal caliber and relieve the patient's symptoms. A follow-up study should be obtained immediately after band adjustment to document that luminal caliber has increased adequately and that barium passes freely through the band. If a food impaction is present above the band, deflation of the band may cause the impaction to resolve spontaneously, but endoscopic retrieval of this food is required if the impaction persists following band deflation.

It is important to remember that weight loss results from the restrictive effect of the band, so some degree of stomal narrowing is required for the patient to experience early satiety and weight loss. Nevertheless, there is disagreement about the optimal degree of stomal narrowing after band placement, with some authors favoring a luminal diameter of only 3–5 mm (49,50).

Though some surgeons routinely adjust gastric bands in their office without benefit of fluoroscopy or a barium study, others perform the adjustments in conjunction with a radiologist in the fluoroscopy suite, not only to utilize fluoroscopy for accessing the subcutaneous port, but also to obtain barium studies immediately after each adjustment. If there is excessive luminal narrowing or obstruction (Fig 15a), some of the administered saline can be withdrawn from the band via the subcutaneous port before repeating the barium study to document that the band has been adequately adjusted (Fig 15b). Swenson et al (51) found that a barium study after band adjustment yielded useful information leading to readjustment of the band after 7% of routine band adjustments.

Malpositioned band.—Malpositioning of the band is an unusual complication that occurs at the time of surgical placement, most often when this procedure is performed by an inexperienced surgeon. If the band is placed in the perigastric fat, it fails to encompass the stomach, so there is no restrictive effect on the lumen. In other patients, the band inadvertently may be placed inferiorly around the lower stomach, causing gastric outlet obstruction.

Pouch dilation.—Acute pouch dilation usually results from marked stomal narrowing secondary to overfilling of the band or from distal band slippage and obstruction (see next section). In this setting, the band should be deflated to prevent further complications, including irreversible pouch dilation and progressive band slippage (17,48,52). Chronic pouch dilation may also develop in the presence of a normal stomal diameter and is usually secondary to chronic volume overload of the pouch in patients who fail to modify their eating habits after band placement (46,49). This complication has been reported in 3%–8% of patients (52,53). Barium studies may show concentric dilation of the gastric pouch with retained food in the pouch, esophageal dilation above the pouch, and a normal to widened stoma (46). In this setting, nutritional counseling is required (48).

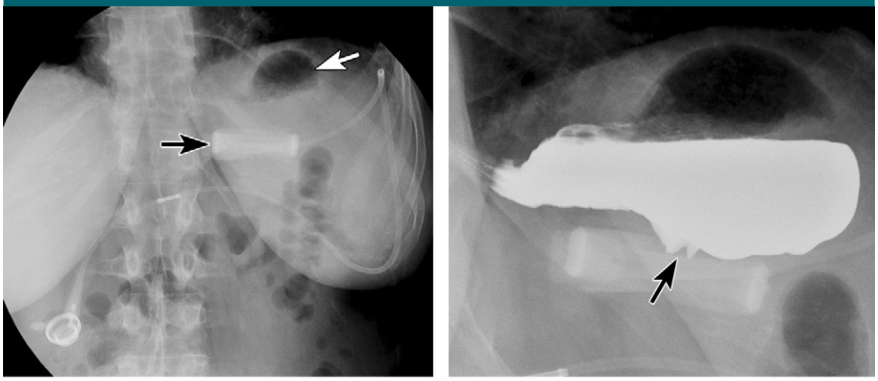
Distal band slippage.—Distal band slippage is a relatively common complication of band placement, occurring in 4%–13% of patients (46). This complication is thought to result from recurrent vomiting, overinflation of the band, or faulty surgical technique and can be posterior or anterior (54). Posterior slippage is associated with upward herniation of the posterior gastric wall through the band, whereas anterior slippage is associated with downward displacement of the band over the anterior aspect of the stomach (46). With both forms of slippage, the band is no longer positioned near the gastroesophageal junction, but instead surrounds the stomach more distally, with herniation of the gastric fundus above the band. Band slippage is often associated with luminal narrowing and obstruction by the band. As a result, affected individuals may present with vomiting, regurgitation, and food intolerance (46). Severe band slippage occasionally may be complicated by the development of gastric volvulus with infarction and perforation of the stomach, a potentially life-threatening condition (see later section, Gastric Volvulus).

Band slippage is often recognized on abdominal radiographs by increased separation between the gastric band and the medial aspect of the left hemidiaphragm. The slipped band also tends to have a more horizontal orientation, with a phi angle greater than 58° (Fig 17a) (47). As the stomach herniates superiorly through a slipped gastric band, the weight of the herniated stomach sometimes causes the band to tilt along its horizontal axis, so the anterior and posterior sides of the band are no longer superimposed, producing an O-shaped configuration (also known as the O sign), a finding highly suggestive of distal band slippage (55). If the slipped band is causing obstruction, an air-fluid level may be present in a dilated gastric pouch above the band (Fig 17a).

Barium studies can readily demonstrate distal slippage of the band, with the band surrounding the lower gastric fundus, body, or even antrum. This complication is often associated with stomal narrowing and obstruction manifested by eccentric dilation of the gastric pouch and delayed emptying of barium through the band (Fig 17b). The dilated gastric pouch is usually posterior and inferior in patients with posterior slippage and anterior and superior in patients with anterior slippage (46).

When band slippage is documented on barium studies, all residual fluid is usually removed from the band to decrease luminal narrowing and alleviate or prevent obstruction. The barium study should be repeated immediately after band adjustment to document that the band stoma is now patent. If not, surgical removal of the band may be required. If

Figure 17



a. b.

Figure 17: Distal band slippage with obstruction. **(a)** Upright scout image of upper abdomen shows abnormal position of band (black arrow), which is located more inferiorly than usual and has a transverse orientation (with phi angle of about 90°). Also note air-fluid level within gastric pouch (white arrow) above band. **(b)** Upright frontal spot image from single-contrast upper GI barium study shows marked narrowing and high-grade obstruction of lumen (arrow) by slipped band, with markedly dilated gastric pouch above band. This obstruction resolved after removal of all fluid from band.

Figure 18

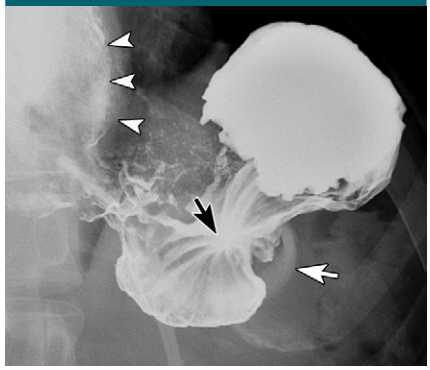


Figure 18: Distal band slippage with gastric volvulus. Supine spot image from single-contrast upper GI barium study shows marked distal slippage of band (white arrow), with converging gastric folds (black arrow) due to twisting of dilated stomach above band. Also note high-grade obstruction with no barium entering stomach distal to band and dilated, fluid-filled esophagus proximally (arrowheads). This patient made a complete recovery after the band was removed surgically.

the band stoma is patent, a follow-up barium study should be performed 7–14 days later to determine whether the deflated band has returned to its usual location beneath the left hemidiaphragm and whether pouch dilation has resolved. If so, additional saline can be administered incrementally into the band through a new series of periodic adjustments to promote further weight loss. If band slippage persists on one or more follow-up barium studies, however, the band should be surgically repositioned, removed, or replaced.

Perforation.—Acute gastric perforation is a rare complication of laparoscopic gastric banding, occurring in less than 1% of patients (46,56). This complication presumably results from trauma to the gastric wall at surgery. Affected individuals typically present with upper abdominal pain, fever, leukocytosis, and tachychardia. Upper GI studies may reveal contained or even free extravasation of water-soluble contrast material from the site of perforation, and CT images may show extraluminal gas or fluid collections in the left upper quadrant (10).

Gastric volvulus.—Gastric volvulus is a rare complication of gastric banding that occurs when there is band slippage with twisting of the prolapsed proximal stomach around the band, causing closed-loop obstruction (57). This condition is potentially life-threatening because the torsed stomach is at risk for strangulation, ischemia, and infarction. When high-grade obstruction is present, affected individuals are likely to present with severe nausea and vomiting (57). Barium studies may reveal twisting of the prolapsed stomach around the band, causing the body of the stomach to rotate upwards and to the left, so it is located above the fundus (57). This is often associated with marked narrowing and high-grade obstruction of the lumen where it traverses the band (Fig 18) (57). If ischemia and/or infarction of the stomach are present, CT scans may show thickening of the gastric wall and gastric pneumatosis. Even in patients with severe vascular compromise, however, this gastric ischemia often resolves after the band is removed and the normal vascular supply to the stomach is restored. Gastric volvulus therefore represents an indication for immediate surgery and urgent removal of the band before the development of gastric infarction and perforation (57).

Intraluminal band erosion.—Band erosion into the gastric lumen is a rare but late complication of laparoscopic adjustable gastric banding that occurs in less than 2% of patients (58). This complication may result from high pressures generated by the inflated band, with pressure necrosis of the adjacent gastric wall and subsequent erosion of the band into the lumen. There usually is incomplete erosion of the band into the stomach (58), but the entire band occasionally may erode into the lumen (59). With complete intraluminal erosion, the band can migrate distally and become lodged in the gastric antrum, duodenum, or proximal jejunum, causing mechanical obstruction (60–62). Rarely, the intraluminal band can even migrate in a retrograde fashion to the gastroesophageal junction, causing obstruction at the cardia (59). Intraluminal erosion of the band usually warrants band removal because of the risk of obstruction, severe upper GI bleeding, or perforation (49,58).

Intraluminal band erosion into the stomach may be manifested on upper GI examination or CT scan by passage of barium around the intraluminal portion of the band (Fig 19) (63) or around all sides of the band if it has eroded com-

Figure 19

Figure 19: Gastric band partially eroding into gastric lumen. Axial CT image after oral and intravenous contrast material administration shows that lateral aspect of band device has eroded into lumen of stomach. Note contrast material (arrow) and a tiny focus of gas medial to eroded portion of band.

Figure 20

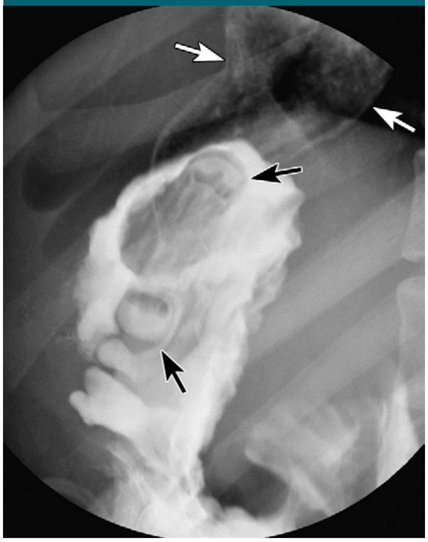


Figure 20: Gastric band completely eroding into gastric lumen with partial obstruction. Lateral spot image from single-contrast upper GI barium study shows barium completely surrounding band (black arrows), which has migrated to cardia and is causing partial obstruction with dilated, fluid-filled esophagus (white arrows) above band. The band was removed surgically. (Reprinted, with permission, from reference 59.)

Figure 21

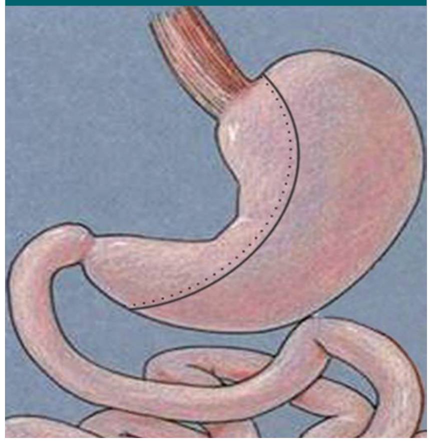


Figure 21: Diagram shows normal surgical anatomy after laparoscopic sleeve gastrectomy. Note how stomach is resected along greater curvature of fundus, body, and proximal antrum, producing a narrow, banana-shaped pouch along lesser curvature.

Figure 22

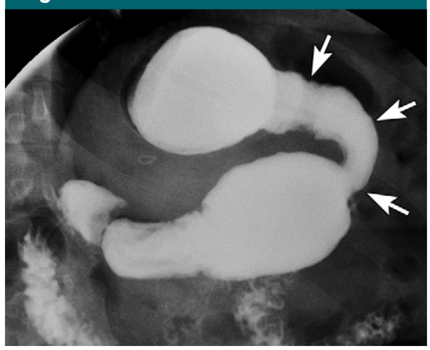


Figure 22: Normal imaging findings after sleeve gastrectomy. Supine spot image from single-contrast upper GI barium study shows tubular narrowing of gastric pouch (arrows) secondary to resection of greater curvature of proximal and mid stomach. Note relatively abrupt widening of gastric antrum, which is preserved.

pletely into the lumen (Fig 20) (59). When an intraluminal band migrates distally into the antrum or small bowel or proximally to the cardia, barium studies may reveal high-grade obstruction (Fig 20) (59), necessitating immediate removal of the band.

Port- and band-related complications.—Port-related complications of laparoscopic gastric banding include infections and port eversion. The band system can also fail if the port, tubing, or band becomes disconnected or if the tubing is kinked or disrupted (49). The latter complications are readily detected on abdominal radiographs. Rarely, the tubing can erode into the lumen of the stomach, duodenum, or even the colon, causing recurrent port site infections (64). This complication can be diagnosed on barium studies or CT scans by documenting the intraluminal location of the tubing (64). Confirmed intraluminal erosion of the tubing necessitates surgical removal of the tubing to prevent continued infections (64).

Laparoscopic Sleeve Gastrectomy

Laparoscopic sleeve gastrectomy is a relatively recent surgical technique introduced in 1999 (65). This procedure was estimated to account for about 5% of all bariatric surgery in 2008 (66). Sleeve gastrectomy is a procedure in which a long, narrow gastric pouch is created by removing about 75% of the stomach, promoting weight loss by means of the restrictive effect of the pouch (10). Unlike gastric banding, there is no need for periodic adjustments with sleeve gastrectomy (67), but this procedure is irreversible.

Surgical Anatomy

Sleeve gastrectomy is performed by laparoscopically dividing the stomach along its long axis and resecting the greater curvature of the fundus, body, and proximal antrum, producing a narrow, banana-shaped gastric pouch along the lesser curvature (Fig 21) (10). The remaining stomach has a residual volume of only about 100 mL, causing the patient to experience early satiety and weight loss (10).

Normal Imaging Features

Upper GI examination.—Upper GI examinations typically reveal a long, tubular gastric pouch in patients with a laparoscopic sleeve gastrectomy (Fig 22) (67). Because the distal gastric antrum is preserved, there may be a relatively abrupt segment of widening at the distal end of the pouch. Some patients may have transient retention of barium in the proximal end of the pouch because of loss of peristalsis during the early postoperative period (68). Occasionally, a

Radiology

Figure 23

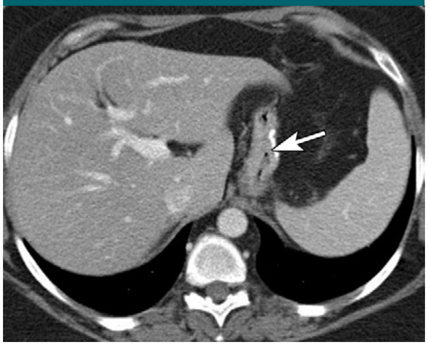
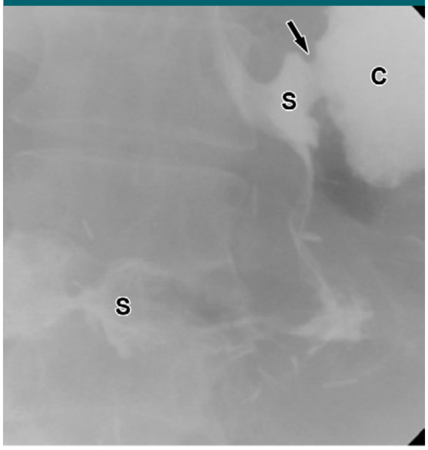
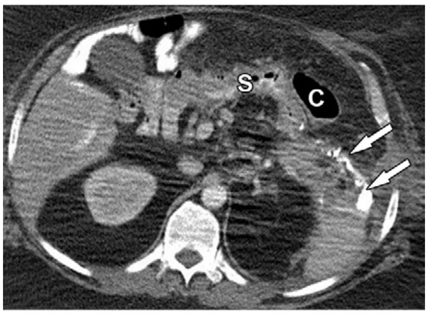


Figure 23: Normal appearance of sleeve gastrectomy at CT. Axial CT image after oral and intravenous contrast material administration show a small-caliber, tubular stomach after resection along greater curvature. Note surgical suture line (arrow). There is prominent fat attenuation in surgical bed.

Figure 24



a.



b.

Figure 24: Sleeve gastrectomy with postoperative leak. **(a)** Supine spot image from upper GI examination with water-soluble contrast material shows focal leak (arrow) from proximal stomach laterally into extraluminal collection in left upper quadrant *(C)*. (*S* = gastric sleeve.) **(b)** Axial CT image after oral and intravenous contrast material administration shows tubular stomach *(S)*, with extraluminal collection *(C)* of gas and extravasated contrast material (arrows) in left upper quadrant due to postoperative leak.

Figure 25

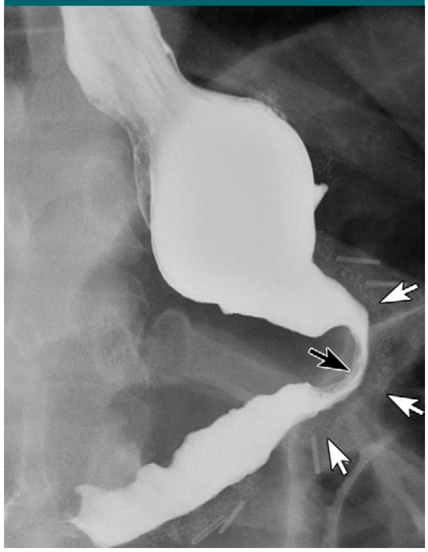


Figure 25: Sleeve gastrectomy with stricture and obstruction. Supine spot image from single-contrast upper GI barium study shows short segment of marked narrowing (black arrow) in gastric pouch. Also note dilation of stomach and esophagus proximally. (White arrows = staple line abutting greater curvature.)

linear outpouching or surgical placation defect in a residual portion of nonexcised gastric fundus can mimic the appearance of an extraluminal leak (10).

Abdominal CT.—CT may be performed after laparoscopic sleeve gastrectomy to assess for abscesses, perforation, staple line dehiscence, and other complications such as splenic injury or infarction. CT typically reveals a narrowed, tubular stomach that has a smaller caliber along its long axis. A staple line is typically identified along the greater curvature of the residual stomach (Fig 23), but no Roux limb is seen when a sleeve gastrectomy is performed as a stand-alone surgical procedure. In contrast, a jejunal Roux limb may be visualized in the left upper quadrant when a sleeve gastrectomy is performed as the restrictive component in conjunction with a Roux-en-Y gastric bypass. Abundant mesenteric fat is often identified in the expected location of the resected portion of the stomach (Fig 23).

Complications

Gastric leaks.—Gastric leaks are a potential concern after laparoscopic sleeve gastrectomy because of the length of the staple line along the greater curvature of the gastric pouch. Surprisingly, however, postoperative leaks have been reported in less than 1% of patients after this form of surgery (65). Affected individuals typically present with pain, fever, and leukocytosis. Leaks most commonly occur from the proximal end of the staple line near the gastroesophageal junction (69), often extending laterally from the greater curvature staple line, and are usually manifested on upper GI examinations by extravasation of water-soluble contrast material into extraluminal tracks or collections in the left upper quadrant (Fig 24a). If no leak is detected with a water-soluble contrast agent, high-density barium should be administered to rule out subtle leaks that might otherwise be missed (19). CT scans may demonstrate the site of leakage as well as localized extraluminal collections or abscesses in this region (Fig 24b).

Gastric strictures and gastric outlet obstruction.—Some patients develop symptoms of gastric outlet obstruction when scarring along the greater curvature staple line causes marked narrowing of the pouch. Barium studies may reveal focal strictures or long segments of narrowing with delayed emptying of barium from the residual stomach (Fig 25). Focal strictures may respond to endoscopic dilation, but longer segments of narrowing occasionally necessitate surgical revision or resection of the pouch.

Gastric dilation.—Gastric dilation is another complication of sleeve gastrectomy, necessitating surgical revision of the pouch in about 4.5% of patients (65). Affected individuals present with inadequate weight loss or recurrent weight gain. Barium studies may reveal widening of the gastric sleeve, which no longer has a tubular appearance.

Gastroesophageal reflux.—Sleeve gastrectomy is thought to predispose to the development of postoperative gastroesophageal reflux, possibly because of the distorted gastric anatomy and stasis caused by the procedure. The frequency of reflux symptoms 1 year after surgery may be as high as 20% (70). Such reflux can be detected on barium studies.

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References

1. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999-2004. JAMA 2006;295(13):1549–1555.
2. Getting a handle on obesity. Lancet 2002;359(9322):1955.
3. Cawley J, Meyerhoefer C. The medical care costs of obesity: an instrumental variables approach. J Health Econ 2012;31(1):219–230.
4. Buchwald H; Consensus Conference Panel. Consensus conference statement bariatric surgery for morbid obesity: health implications for patients, health professionals, and third-party payers. Surg Obes Relat Dis 2005;1(3):371–381.
5. Gastrointestinal surgery for severe obesity. Proceedings of a National Institutes of Health Consensus Development Conference. March 25-27, 1991, Bethesda, MD. Am J Clin Nutr 1992;55(2 Suppl):487S–619S.
6. Santry HP, Gillen DL, Lauderdale DS. Trends in bariatric surgical procedures. JAMA 2005;294(15):1909–1917.
7. Cummings DE, Overduin J, Foster-Schubert KE. Gastric bypass for obesity: mechanisms of weight loss and diabetes resolution. J Clin Endocrinol Metab 2004;89(6):2608–2615.
8. Scheirey CD, Scholz FJ, Shah PC, Brams DM, Wong BB, Pedrosa M. Radiology of the laparoscopic Roux-en-Y gastric bypass procedure: conceptualization and precise interpretation of results. RadioGraphics 2006;26(5):1355–1371.
9. Quigley S, Colledge J, Mukherjee S, Patel K. Bariatric surgery: a review of normal postoperative anatomy and complications. Clin Radiol 2011;66(10):903–914.
10. Shah S, Shah V, Ahmed AR, Blunt DM. Imaging in bariatric surgery: service set-up, post-operative anatomy and complications. Br J Radiol 2011;84(998):101–111.
11. Jha S, Levine MS, Rubesin SE, et al. Detection of strictures on upper gastrointestinal tract radiographic examinations after laparoscopic Roux-en-Y gastric bypass surgery: importance of projection. AJR Am J Roentgenol 2006;186(4):1090–1093.
12. Carucci LR, Turner MA, Conklin RC, DeMaria EJ, Kellum JM, Sugerman HJ. Roux-en-Y gastric bypass surgery for morbid obesity: evaluation of postoperative extraluminal leaks with upper gastrointestinal series. Radiology 2006;238(1):119–127.
13. Smith TR, White AP. Narrowing of the proximal jejunal limbs at their passage through the transverse mesocolon: a potential pitfall of laparoscopic Roux-en-Y gastric bypass. AJR Am J Roentgenol 2004;183(1):141–143.
14. Carucci LR, Turner MA, Yu J. Imaging evaluation following Roux-en-Y gastric bypass surgery for morbid obesity. Radiol Clin North Am 2007;45(2):247–260.
15. Carucci LR. Imaging obese patients: problems and solutions. Abdom Imaging 2013;38(4):630–646.
16. Yu J, Turner MA, Cho SR, et al. Normal anatomy and complications after gastric bypass surgery: helical CT findings. Radiology 2004;231(3):753–760.
17. Blachar A, Federle MP, Pealer KM, Ikramuddin S, Schauer PR. Gastrointestinal complications of laparoscopic Roux-en-Y gastric bypass surgery: clinical and imaging findings. Radiology 2002;223(3):625–632.
18. Buckwalter JA, Herbst CA Jr. Leaks occurring after gastric bariatric operations. Surgery 1988;103(2):156–160.
19. Swanson JO, Levine MS, Redfern RO, Rubesin SE. Usefulness of high-density barium for detection of leaks after esophagogastrectomy, total gastrectomy, and total laryngectomy. AJR Am J Roentgenol 2003;181(2):415–420.
20. Chandler RC, Srinivas G, Chintapalli KN, Schwesinger WH, Prasad SR. Imaging in bariatric surgery: a guide to postsurgical anatomy and common complications. AJR Am J Roentgenol 2008;190(1):122–135.
21. Spaulding L. The impact of small bowel resection on the incidence of stomal stenosis and marginal ulcer after gastric bypass. Obes Surg 1997;7(6):485–487; discussion 488.
22. Ahmad J, Martin J, Ikramuddin S, Schauer P, Slivka A. Endoscopic balloon dilation of gastroenteric anastomotic stricture after laparoscopic gastric bypass. Endoscopy 2003;35(9):725–728.
23. Sanyal AJ, Sugerman HJ, Kellum JM, Engle KM, Wolfe L. Stomal complications of gastric bypass: incidence and outcome of therapy. Am J Gastroenterol 1992;87(9):1165–1169.
24. Rasmussen JJ, Fuller W, Ali MR. Marginal ulceration after laparoscopic gastric bypass: an analysis of predisposing factors in 260 patients. Surg Endosc 2007;21(7):1090–1094.
25. Dallal RM, Bailey LA. Ulcer disease after gastric bypass surgery. Surg Obes Relat Dis 2006;2(4):455–459.
26. Sapala JA, Wood MH, Sapala MA, Flake TM Jr. Marginal ulcer after gastric bypass: a prospective 3-year study of 173 patients. Obes Surg 1998;8(5):505–516.
27. Silver R, Levine MS, Williams NN, Rubesin SE. Using radiography to reveal chronic jejunal ischemia as a complication of gastric bypass surgery. AJR Am J Roentgenol 2003;181(5):1365–1367.
28. Ruutiainen AT, Levine MS, Williams NN. Giant jejunal ulcers after Roux-en-Y gastric bypass. Abdom Imaging 2008;33(5):575–578.
29. Champion JK, Williams M. Small bowel obstruction and internal hernias after laparoscopic Roux-en-Y gastric bypass. Obes Surg 2003;13(4):596–600.
30. Filip JE, Mattar SG, Bowers SP, Smith CD. Internal hernia formation after laparoscopic Roux-en-Y gastric bypass for morbid obesity. Am Surg 2002;68(7):640–643.
31. Carucci LR, Turner MA, Shaylor SD. Internal hernia following Roux-en-Y gastric bypass surgery for morbid obesity: evaluation of radiographic findings at small-bowel examination. Radiology 2009;251(3):762–770.
32. Tucker ON, Escalante-Tattersfield T, Szomstein S, Rosenthal RJ. The ABC system: a simplified classification system for small bowel obstruction after laparoscopic Roux-en-Y gastric bypass. Obes Surg 2007;17(12):1549–1554.
33. Carucci LR. Role of imaging in bariatric procedures: Roux-en-Y gastric bypass and laparoscopic adjustable gastric banding. Imaging Med 2011;3(1):81–92.
34. Iannelli A, Buratti MS, Novellas S, et al. Internal hernia as a complication of laparoscopic Roux-en-Y gastric bypass. Obes Surg 2007;17(10):1283–1286.
35. Higa KD, Ho T, Boone KB. Internal hernias after laparoscopic Roux-en-Y gastric bypass: incidence, treatment and prevention. Obes Surg 2003;13(3):350–354.

36. Lockhart ME, Tessler FN, Canon CL, et al. Internal hernia after gastric bypass: sensitivity and specificity of seven CT signs with surgical correlation and controls. AJR Am J Roentgenol 2007;188(3):745–750.

37. Reddy SA, Yang C, McGinnis LA, Seggerman RE, Garza E, Ford KL 3rd. Diagnosis of transmesocolic internal hernia as a complication of retrocolic gastric bypass: CT imaging criteria. AJR Am J Roentgenol 2007;189(1):52–55.

38. Blachar A, Federle MP, Dodson SF. Internal hernia: clinical and imaging findings in 17 patients with emphasis on CT criteria. Radiology 2001;218(1):68–74.

39. Duane TM, Wohlgemuth S, Ruffin K. Intussusception after Roux-en-Y gastric bypass. Am Surg 2000;66(1):82–84.

40. Carucci LR, Conklin RC, Turner MA. Roux-en-Y gastric bypass surgery for morbid obesity: evaluation of leak into excluded stomach with upper gastrointestinal examination. Radiology 2008;248(2):504–510.

41. Goodman P, Halpert RD. Radiological evaluation of gastric stapling procedures for morbid obesity. Crit Rev Diagn Imaging 1991;32(1):37–67.

42. Belachew M, Legrand MJ, Defechereux TH, Burtheret MP, Jacquet N. Laparoscopic adjustable silicone gastric banding in the treatment of morbid obesity: a preliminary report. Surg Endosc 1994;8(11):1354–1356.

43. Provost DA. Laparoscopic adjustable gastric banding: an attractive option. Surg Clin North Am 2005;85(4):789–805, vii.

44. O'Brien PE, Brown WA, Smith A, McMurrick PJ, Stephens M. Prospective study of a laparoscopically placed, adjustable gastric band in the treatment of morbid obesity. Br J Surg 1999;86(1):113–118.

45. Spivak H, Anwar F, Burton S, Guerrero C, Onn A. The Lap-Band system in the United States: one surgeon's experience with 271 patients. Surg Endosc 2004;18(2):198–202.

46. Blachar A, Blank A, Gavert N, Metzer U, Fluser G, Abu-Abeid S. Laparoscopic adjustable gastric banding surgery for morbid obesity: imaging of normal anatomic features and postoperative gastrointestinal complications. AJR Am J Roentgenol 2007;188(2):472–479.

47. Mehanna MJ, Birjawi G, Moukaddam HA, Khoury G, Hussein M, Al-Kutoubi A. Complications of adjustable gastric banding, a radiological pictorial review. AJR Am J Roentgenol 2006;186(2):522–534.

48. Carucci LR, Turner MA, Szucs RA. Adjustable laparoscopic gastric banding for morbid obesity: imaging assessment and complications. Radiol Clin North Am 2007;45(2):261–274.

49. Wiesner W, Schöb O, Hauser RS, Hauser M. Adjustable laparoscopic gastric banding in patients with morbid obesity: radiographic management, results, and postoperative complications. Radiology 2000;216(2):389–394.

50. DeMaria EJ, Sugerman HJ, Meador JG, et al. High failure rate after laparoscopic adjustable silicone gastric banding for treatment of morbid obesity. Ann Surg 2001;233(6):809–818.

51. Swenson DW, Levine MS, Rubesin SE, Williams NN, Dumon K. Utility of routine barium studies after adjustments of laparoscopically inserted gastric bands. AJR Am J Roentgenol 2010;194(1):129–135.

52. Hainaux B, Coppens E, Sattari A, Vertruyen M, Hubloux G, Cadière GB. Laparoscopic adjustable silicone gastric banding: radiological appearances of a new surgical treatment for morbid obesity. Abdom Imaging 1999;24(6):533–537.

53. Mortelé KJ, Pattijn P, Mollet P, et al. The Swedish laparoscopic adjustable gastric banding for morbid obesity: radiologic findings in 218 patients. AJR Am J Roentgenol 2001;177(1):77–84.

54. Wiesner W, Weber M, Hauser RS, Hauser M, Schoeb O. Anterior versus posterior slippage: two different types of eccentric pouch dilatation in patients with adjustable laparoscopic gastric banding. Dig Surg 2001;18(3):182–186; discussion 187.

55. Pieroni S, Sommer EA, Hito R, Burch M, Tkacz JN. The "O" sign, a simple and helpful tool in the diagnosis of laparoscopic adjustable gastric band slippage. AJR Am J Roentgenol 2010;195(1):137–141.

56. Weiner R, Blanco-Engert R, Weiner S, Matkowitz R, Schaefer L, Pomhoff I. Outcome after laparoscopic adjustable gastric banding: 8 years experience. Obes Surg 2003;13(3):427–434.

57. Kicska G, Levine MS, Raper SE, Williams NN. Gastric volvulus after laparoscopic adjustable gastric banding for morbid obesity. AJR Am J Roentgenol 2007;189(6):1469–1472.

58. Nocca D, Frering V, Gallix B, et al. Migration of adjustable gastric banding from a cohort study of 4236 patients. Surg Endosc 2005;19(7):947–950.

59. Ruutiainen AT, Levine MS, Dumon K. Intraluminal erosion and retrograde migration of laparoscopic gastric band with high-grade obstruction at gastroesophageal junction. Surg Obes Relat Dis 2012;8(2):e14–e16.

60. Pinsk I, Dukhno O, Levy I, Ovnat A. Gastric outlet obstruction caused by total band erosion. Obes Surg 2004;14(9):1277–1279.

61. Taskin M, Zengin K, Unal E. Intraluminal duodenal obstruction by a gastric band following erosion. Obes Surg 2001;11(1):90–92.

62. Lantsberg L, Kirshtein B, Leytzin A, Makarov V. Jejunal obstruction caused by migrated gastric band. Obes Surg 2008;18(2):225–227.

63. Hainaux B, Agneessens E, Rubesova E, et al. Intragastric band erosion after laparoscopic adjustable gastric banding for morbid obesity: imaging characteristics of an underreported complication. AJR Am J Roentgenol 2005;184(1):109–112.

64. Cintolo JA, Levine MS, Huang S, Dumon K. Intraluminal erosion of laparoscopic gastric band tubing into duodenum with recurrent port-site infections. J Laparoendosc Adv Surg Tech A 2012;22(6):591–594.

65. Gumbs AA, Gagner M, Dakin G, Pomp A. Sleeve gastrectomy for morbid obesity. Obes Surg 2007;17(7):962–969.

66. Buchwald H, Oien DM. Metabolic/bariatric surgery worldwide 2008. Obes Surg 2009;19(12):1605–1611.

67. Carucci LR, Turner MA. Imaging following bariatric procedures: Roux-en-Y gastric bypass, gastric sleeve, and biliopancreatic diversion. Abdom Imaging 2012;37(5):697–711.

68. Goitein D, Goitein O, Feigin A, Zippel D, Papa M. Sleeve gastrectomy: radiologic patterns after surgery. Surg Endosc 2009;23(7):1559–1563.

69. Burgos AM, Braghetto I, Csendes A, et al. Gastric leak after laparoscopic-sleeve gastrectomy for obesity. Obes Surg 2009;19(12):1672–1677.

70. Himpens J, Dapri G, Cadière GB. A prospective randomized study between laparoscopic gastric banding and laparoscopic isolated sleeve gastrectomy: results after 1 and 3 years. Obes Surg 2006;16(11):1450–1456.