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RadioGraphics

Laparoscopic Adjustable Gastric Banding: What Radiologists Need to Know[1]

TEACHING POINTS
See last page

Sushilkumar K. Sonavane, MD • Christine O. Menias, MD • Kartikeya P. Kantawala, MD, DMRD • Alampady K. Shanbhogue, MD • Srinivasa R. Prasad, MD • John C. Eagon, MD • Kumaresan Sandrasegaran, MD

Laparoscopic adjustable gastric banding (LAGB) is performed with increasing frequency for the management of morbid obesity. Although LAGB is less invasive than other bariatric surgical procedures, it is associated with various complications that may lead to nonspecific abdominal symptoms several months or years after the procedure. Because complications of LAGB may be encountered incidentally at imaging for other indications, all radiologists should be familiar with the appearances of correctly positioned and malpositioned gastric bands, normal and abnormal appearances of the postprocedural pouch and stomach, and imaging features suggestive or indicative of early or delayed complications of LAGB. Familiarity with the techniques and systems currently approved by the Food and Drug Administration for use in this procedure may help radiologists detect postoperative complications and guide their management. Both commercially available systems include a silicone gastric band with an inflatable inner surface, a reservoir port, and a tube that connects the port to the gastric band. All these components of LAGB systems should be visible at radiologic imaging; however, older models of gastric bands may not be radiopaque and therefore may not be depicted on images. The most common complications of LAGB are gastric band slippage and associated pouch dilatation, intragastric erosion of the band, gastric perforation, and abscess formation. Complications that occur with less frequency include tube migration, tube disconnection, port-site infection, and small bowel obstruction.

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Abbreviations: AP = anteroposterior, FDA = Food and Drug Administration, GI = gastrointestinal, LAGB = laparoscopic adjustable gastric banding

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[1]From the Department of Cardiopulmonary Radiology, University of Alabama at Birmingham, 619 19th St, S JT N370, Birmingham, AL 35294 (S.K.S.); Department of Abdominal Radiology (C.O.M.) and Department of Surgery, Section of Minimally Invasive Surgery (J.C.E.), Mallinckrodt Institute of Radiology, Barnes Jewish Hospital, Washington University School of Medicine, St Louis, Mo; Departments of Pediatric Radiology (K.P.K.) and Abdominal Radiology (K.S.), Indiana University School of Medicine, Indianapolis, Ind; Department of Radiology, University of Texas Health Science Center at San Antonio, San Antonio, Tex (A.K.S.); and Department of Radiology, University of Texas M. D. Anderson Cancer Center, Houston, Tex (S.R.P.). Presented as an education exhibit at the 2010 RSNA Annual Meeting. Received November 18, 2011; revision requested December 15; final revision received March 7, 2012; accepted March 9. K.S. has disclosed a financial relationship (see p 1177); all other authors have no financial relationships to disclose. **Address correspondence to** S.K.S. (e-mail: *ssonavane@uabmc.edu*).

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Introduction

Body mass index, which is determined by dividing body weight in kilograms by the square of height in meters, is traditionally used as a measure of obesity. A body mass index between 25 and 29 kg/m^2 indicates overweight; an index between 30 and 39 kg/m^2, obesity; and an index of more than 40 kg/m^2, morbid obesity (1). One-third (33.8%) of the adult population in the United States is obese (2). According to the Centers for Disease Control and Prevention, in 2010 no state had a prevalence of obesity lower than 20%. Obesity is one of the most important health issues facing the nation, and it causes or is associated with many long-term health problems, including heart and lung diseases, type 2 diabetes mellitus, hypertension, osteoarthritis, sleep apnea, and psychosocial stress (1,3).

Options for the management of obesity include medical, behavioral, and surgical methods, with surgery being the most reliable long-term solution (1,3). With the increased application of laparoscopic surgical techniques, the number of bariatric procedures performed in the United States for treatment of morbid obesity has grown substantially (3,4); from 2003 to 2008, the number of procedures performed increased more than 90% (5).

Laparoscopic adjustable gastric banding (LAGB) is one of the most frequently used and least invasive surgical treatments for morbid obesity (6,7). This article describes the techniques and systems used in laparoscopic gastric banding, postprocedural imaging appearances of correctly positioned and malpositioned bands, normal and abnormal imaging appearances of the altered gastric anatomy, and imaging features suggestive or indicative of postprocedural complications. Methods for managing various kinds of complications are also briefly discussed.

Techniques and Systems

Adjustable gastric banding, first performed with open laparotomy by Kuzmak (8,9) and further developed as a laparoscopic procedure by Belachew and colleagues in 1993 (10), is a purely restrictive surgical procedure that works by limiting the amount of food intake. A laparoscopic technique for adjustable gastric band placement (ie, LAGB) was approved by the Food and Drug Administration (FDA) in 2001 for treatment of morbid obesity (11). Other bariatric surgical procedures that are commonly performed to treat morbid obesity include vertical banded gastroplasty, Roux-en-Y gastric bypass, and biliopancreatic diversion with duodenal switch (12). In comparison with these procedures, LAGB has several advantages: It is minimally invasive, involves no incision or stapling of the stomach or small bowel, and is associated with a lower risk for malnutrition. In addition, the stoma size is adjustable according to the patient's needs, and the belt is more easily removed when restoration of the normal gastric anatomy is desired (11,12).

LAP-BAND (Allergan, Irvine, Calif) (Fig 1a) and REALIZE Adjustable Gastric Band (Ethicon Endo-Surgery, Cincinnati, Ohio) (Fig 1b) are the two FDA-approved, commercially available LAGB systems. Both systems include three components: a radiopaque silicone band with an inflatable inner surface, a reservoir port, and a tube connecting the port with the inflatable band (Fig 1c). The procedure involves laparoscopic placement of the band (Fig 2) around the proximal part of the stomach to create a small pouch. With the pars flaccida technique, the gastric band is placed within 2 cm of the gastroesophageal junction, without penetrating the lesser sac (Fig 3). More distal placement of the gastric band with the perigastric technique is associated with a higher band slippage rate (13). In addition, an anterior fundoplication is performed by stitching the serosa of the anterior wall of the proximal pouch to the adjacent distal stomach, over the band. The band is further attached to a tube that traverses the peritoneum and subcutaneous tissues and connects to a reservoir port, which is usually placed within the anterior abdominal wall to create a stoma (Fig 1c). The stoma size is adjusted by injecting normal saline solution from a noncoring needle into the reservoir to inflate the cuff.

Teaching Point

Normal Imaging Appearances after LAGB Procedures

Radiologic imaging is often performed after LAGB procedures to verify correct positioning of the gastric band and to identify any complications. The modalities most often used for these purposes are abdominal radiography, upper gastrointestinal (GI) tract fluoroscopy, computed tomography (CT), and LAGB system fluoroscopy. Normal postprocedural appearances on images obtained with these modalities are described in the next four sections.

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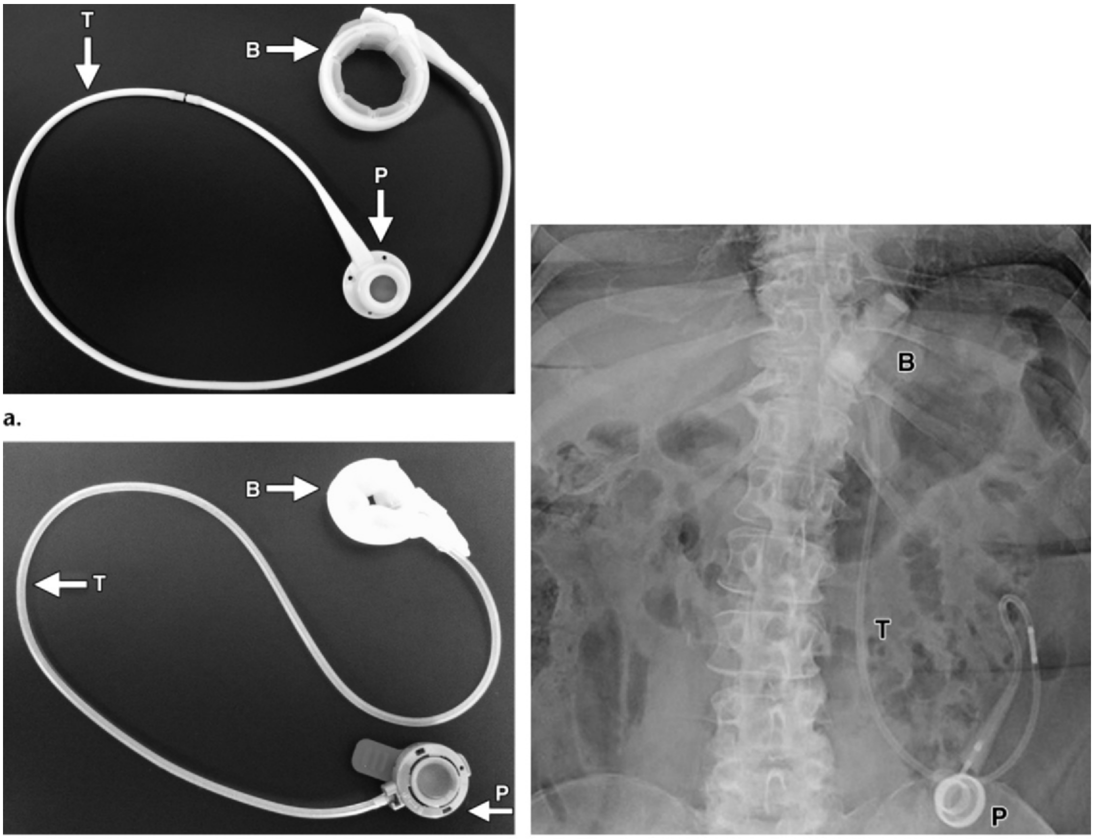


a. b. c.

Figure 1. Components of LAGB systems. **(a, b)** The LAP-BAND Adjustable Gastric Banding System **(a)** and the REALIZE Adjustable Gastric Banding System **(b)** consist of a silicone band *(B),* a connector tube *(T),* and a reservoir port *(P).* **(c)** Anteroposterior (AP) radiograph of the abdomen in a patient who recently underwent an LAGB procedure shows the components of the same apparatus as in **a**. The gastric band *(B)* overlies the left side of the spine just below the level of the left hemidiaphragm, and the reservoir port *(P)* overlies the soft tissues of the left anterior abdominal wall. The connector tube *(T)* can vary in location within the peritoneum.

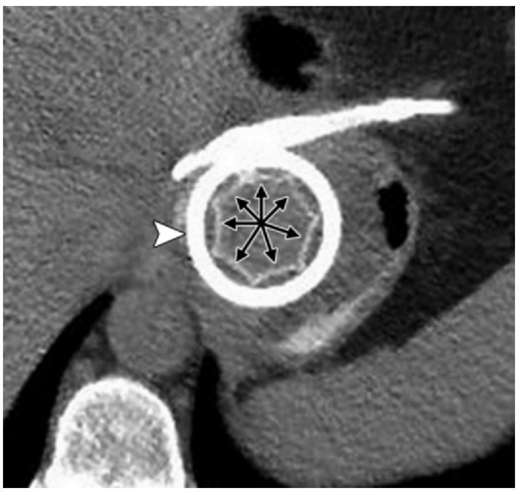


Figure 2. Axial CT image obtained in a 69-year-old woman shows an LAGB device with a radiopaque silicone band (arrowhead) and inflatable inner cuff (black arrows).

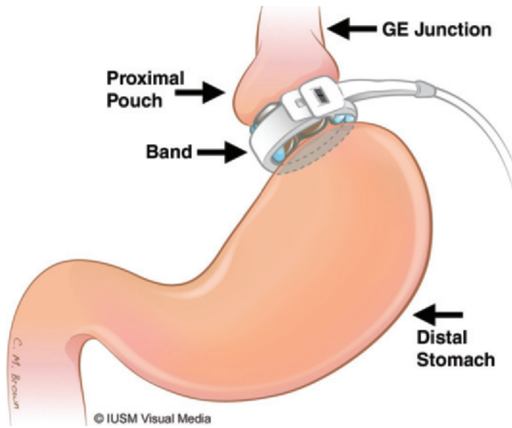
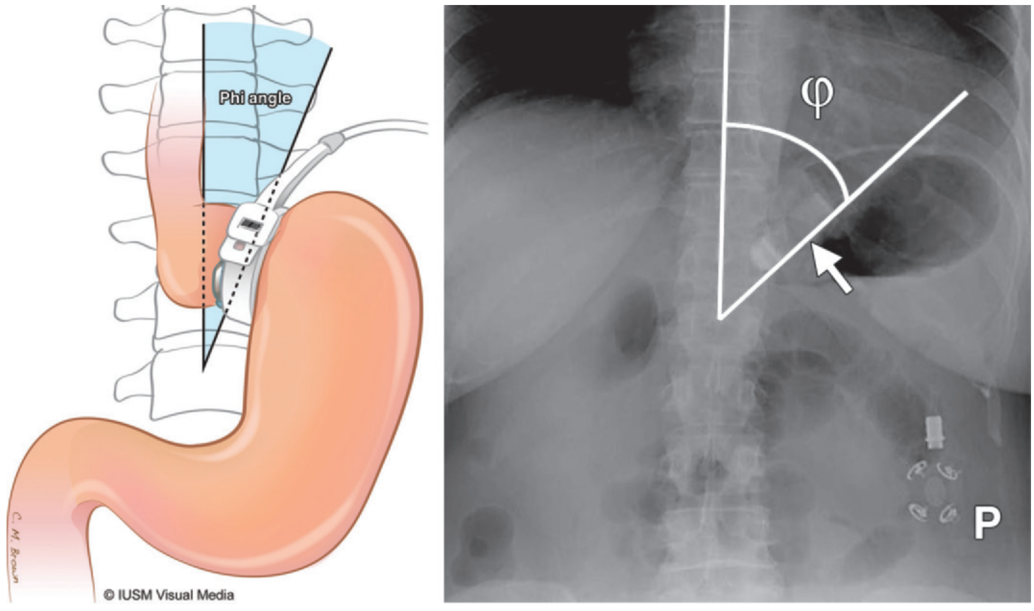


Figure 3. Drawing depicts the altered gastric anatomy after an LAGB procedure. *GE* = gastroesophageal.



a. b.

Figure 4. Drawing **(a)** and AP radiograph **(b)** show how the φ (phi) angle is measured to determine whether a gastric band is correctly positioned. The φ angle is the angle formed by the profile of the gastric band (arrow in **b**) and the vertical axis of the spine on frontal views. If the band is correctly positioned, the φ angle will be between 4° and 58°. Note that the connector tube is not visible because an older model of the REALIZE system was used in this patient. *P* = port.

Abdominal Radiography

Teaching Point

On AP abdominal radiographs, the superior angle formed by the longitudinal axis of the gastric band and the spinal column, which is referred to as the φ (phi) angle, should be between 4° and 58° (13–15). The gastric band should be positioned approximately 5 cm below the left hemidiaphragm and should have a rectangular appearance on AP radiographs because its anterior and posterior aspects are superimposed (Fig 4). There are subtle radiographic differences between the two FDA-approved systems (Table 1). The port for the REALIZE system has four metal barbs or hooks at the periphery for fixation to the anterior rectus fascia. Recent models of the REALIZE band have radiopaque tubing similar to that of the LAP-BAND (Fig 1c), whereas older models have a more radiolucent and flexible connector tube.

Upper GI Tract Fluoroscopy

An initial "scout" abdominal radiograph is obtained to assess the gastric band position and φ angle. The examination begins with the patient standing in a frontal position or at a slight right posterior oblique angle in relation to the x-ray beam so that the gastric band will appear as a rectangle instead of a ring. This position also allows optimal visualization of the stoma through the band. The patient swallows two or three sips of a water-soluble contrast agent such as diatrizoate meglumine and diatrizoate sodium (Gastrografin; Bracco Diagnostics, Princeton, NJ) during intermittent fluoroscopic acquisitions to allow an initial assessment of esophageal caliber, esophageal peristalsis, and the size of the gastric pouch. The patient swallows an additional amount of the oral contrast agent, enough to fully distend the proximal pouch and allow assessment of its dimensions and contours as well as those of the stoma. Additional right posterior oblique spot views are obtained for observation of the fully distended pouch, stoma, and gastric emptying. When distended by a volume of 15–20 mL of the oral contrast agent, the proximal pouch should measure less than 4 cm at its widest diameter, and the stomal diameter should be less than 4 mm. The pouch should begin emptying almost immediately, and emptying should be nearly complete within 15–20 minutes (Fig 5) (14,18,19).

Teaching Point

For inadequate pouch emptying, evidence of contrast material leakage (eg, gastric band opacification) should be carefully sought. In the absence of such leakage, the pouch is further distended with oral contrast medium to allow the identification of eccentric dilatation, an air-fluid level, and any band slippage. With the patient in the right anterior oblique position on a horizontal fluoroscopy table, projections are then performed for observation of gastric emptying; this position facilitates

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Table 1
Comparison of Two Commercially Available LAGB Systems

Characteristic	LAP-BAND	REALIZE
Manufacturer	Allergan, Irvine, Calif	Ethicon Endo-Surgery, Cincinnati, Ohio
Year approved by the FDA	2001	2007
Original model	LAP-BAND	Swedish Adjustable Gastric Band
Weight loss after 1 year	Average loss of 40% of initial excess body weight	Average loss of 40% of initial excess body weight
Other clinical outcomes*	Improvement in control of type 2 diabetes mellitus (>60%), hypertension (>40%), and hyperlipidemia (>50%)	Improvement in control of type 2 diabetes mellitus (>60%), hypertension (>40%), and hyperlipidemia (>50%)
Complications	Slippage, intragastric erosion, and plateau in weight loss	Slippage, intragastric erosion, and plateau in weight loss
Adjustability	Yes	Yes
Adjustment technique	Saline is added or removed with a noncoring needle inserted into the port	Saline is added or removed with a noncoring needle inserted into the port
Timing of first adjustment	4–6 weeks after surgery	4–6 weeks after surgery
Sizes available	Five	Two
Port styles	Three	One
Tube visibility at imaging	Yes	Early models, no; recent models, yes
Method of attachment to fascia	Surgical stitches	Self-attaching metal barbs

Sources.—References 16 and 17.
*Data are percentages of patients with the specified condition who experienced an improvement during the first 3 years after undergoing LAGB.

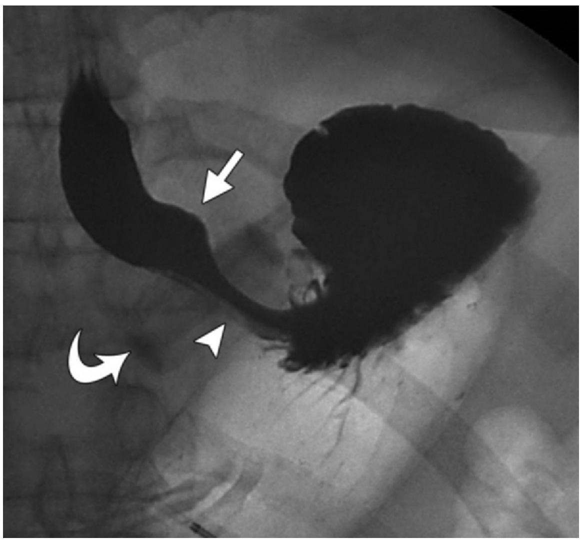


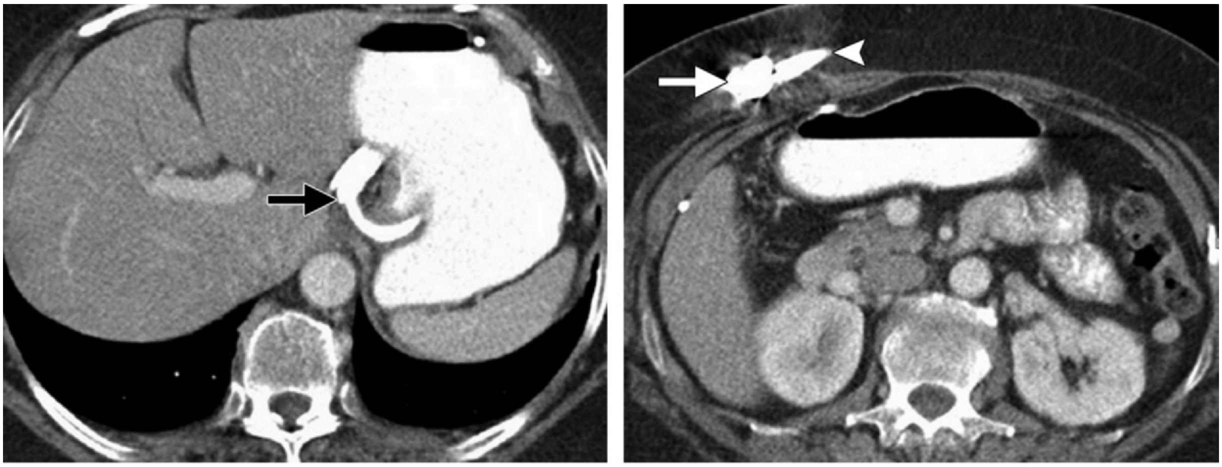
Figure 5. Upper GI tract fluoroscopic image in a 58-year-old woman shows correct positioning of the gastric band (curved arrow); normal emptying of the proximal pouch (straight arrow), which has a diameter of less than 4 cm; and a normal stoma (arrowhead) with a diameter of less than 4 mm.

pouch emptying and assessment of the degree of stomal narrowing. In cases of complete stomal obstruction, decompression may be attempted with needle aspiration of saline content from the reservoir. If the stomal obstruction is not relieved by attempted decompression, retained contrast material in the dilated proximal pouch can be aspirated with fluoroscopic guidance via a temporarily placed nasogastric tube after consultation with the physician who performed the LAGB procedure.

Abdominal CT

CT is not performed routinely immediately after an LAGB procedure. Although it may be performed when the presence of complications of LAGB is suspected, such complications are more often found at CT performed for other indications, perhaps because CT is used with increasing frequency to evaluate patients with nonspecific abdominal symptoms. Given that LAGB is performed with increasing frequency and that patients with abdominal symptoms may present to healthcare centers far from the site where a procedure was performed, radiologists who interpret abdominal CT scans must be familiar with the postprocedural CT appearances of LAGB systems and the altered gastric anatomy.

The CT technique for LAGB evaluation includes oral administration of the water-soluble contrast agent diatrizoate meglumine and diatrizoate sodium, and the area of coverage extends



a. b.

Figure 6. Normal findings at abdominal CT after LAGB in a 49-year-old man. The band was deflated just before CT by the bariatric surgeon, who was concerned about possible band site complications. Axial images show normal appearances of the band (arrow in **a**), connector tube (arrowhead in **b**), and port (arrow in **b**), with no air or fluid collections. Mild soft-tissue stranding seen adjacent to the port in **b** is an expected finding related to instrumentation.

from the lower chest to the iliac crest or the lowest extent of the gastric band observed on a CT topogram. Isotropic CT datasets are acquired, and axial images are reconstructed with a section thickness of 2–5 mm. Multiplanar reformatted images are then obtained from these submillimeter axial image sections.

The CT localizer image and coronal reformatted images should be reviewed to confirm that the φ angle is within the normal range of 4°–58°. The proximal pouch should be ovoid and should have a maximal diameter of less than 4 cm on axial and multiplanar images. The connector tube should be traced in continuity from the port in the anterior abdominal wall to the point where it connects to the gastric band around the gastric pouch. Mild fat stranding resulting from instrumentation may be seen around the port, but no fluid collection should be seen (Fig 6).

LAGB System Fluoroscopy

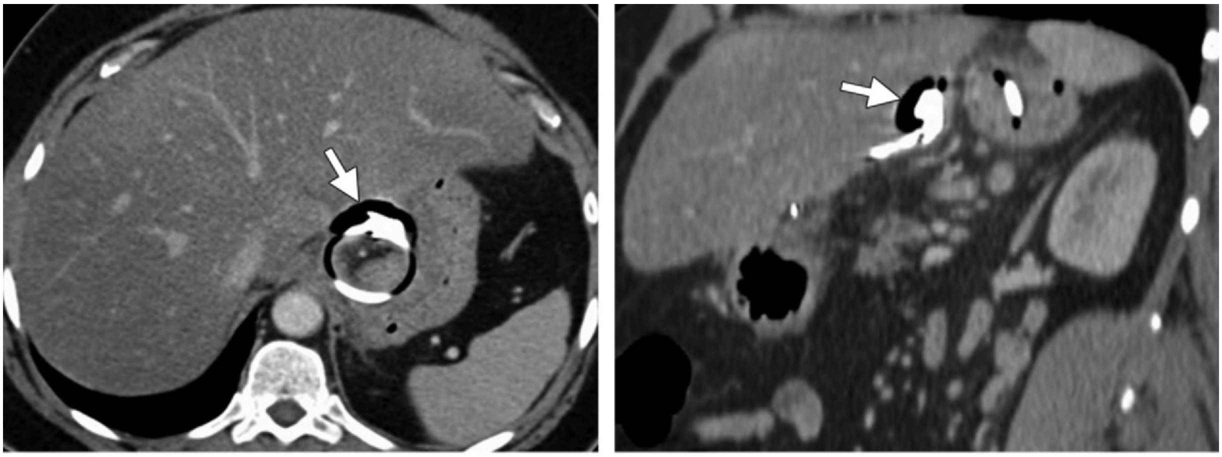
Fluoroscopy may be used to facilitate access to the port in difficult cases or to identify a fluid leak, tube disconnection, or asymmetric band inflation. After an initial scout abdominal radiograph is obtained to assess the gastric band position, port position, and course and continuity of the tube, the patient is positioned supine on the fluoroscopy table. Aseptic technique is used. The port is accessed with a noncoring (Huber) needle while palpation or fluoroscopy is performed for guidance. After the needle is inserted in the port, fluid within the band system is aspirated and its volume is measured. Next, water-soluble contrast material (5–10 mL) is injected slowly into the LAGB system with fluoroscopic guidance and is allowed to remain there for 5–10 minutes to facilitate visualization of any leakage from the port, tube, or band. Serial spot views can be obtained to help diagnose low-volume leakage. Contrast material leakage may be seen in the subcutaneous space around the port or between bowel loops in the peritoneal cavity. The most common sites of leakage are where the port connects with the tube and in coils of tubing near the port that have been inadvertently punctured by needles during access attempts. The patient may be rotated laterally if an oblique projection is needed for better visualization of the entire LAGB system. At the end of the imaging procedure, the contrast material is aspirated from the LAGB system and replaced with sterile saline solution.

Complications

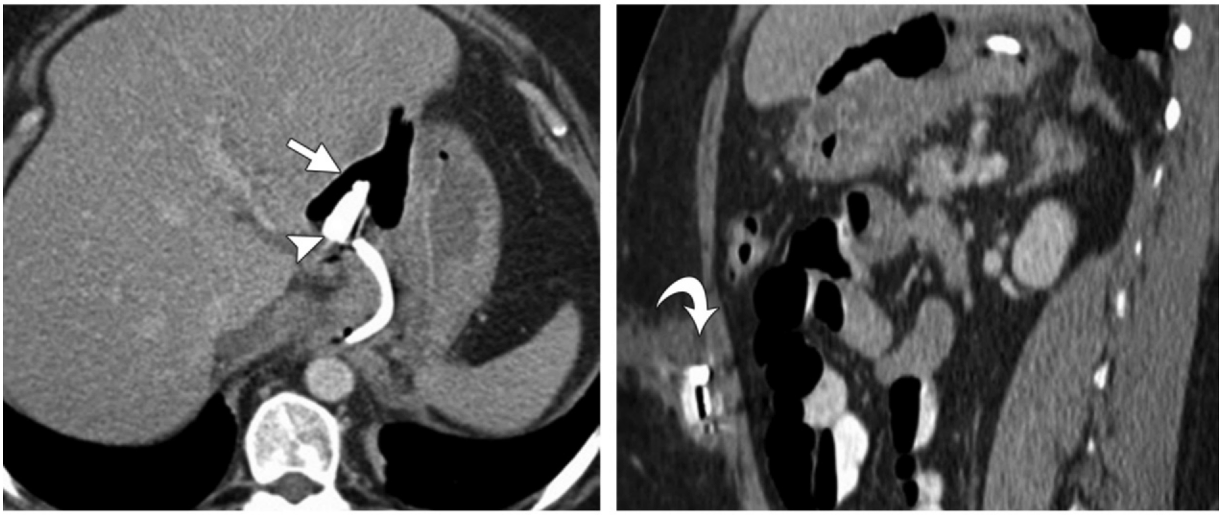
Although LAGB is a minimally invasive surgical procedure, it is associated with early and delayed complications that may result in dysfunction (20–22). Early complications include band malposition, infection, and gastric perforation, which is rare (22). Delayed complications include pouch dilatation associated with gastroesophageal reflux, gastric band slippage, intragastric erosion, and esophageal dilatation and dysmotility. Other possible delayed complications are disconnection of components, port-site infection, and small bowel obstruction.

Band Malposition

The band may be placed inadvertently in the perigastric fat or on the distal stomach, leading



7a. 7b.



8a. 8b.

Figures 7, 8. (7) Gastric perforation in a 55-year-old man with increasing abdominal pain soon after LAGB. Axial **(a)** and sagittal **(b)** CT images show a loculated extraluminal air collection (arrow) adjacent to the gastric band, in the region of the gastrohepatic ligament, a finding suggestive of perforation. In addition, the band is not in an appropriate position surrounding the proximal stomach. **(8)** Gastric perforation and abscess in a 48-year-old woman with fever and acute abdominal pain after LAGB. **(a)** Axial CT image shows the gastric band (arrowhead) in an abnormal position, with an adjacent extraluminal air collection (arrow) in the region of the gastrohepatic ligament, findings indicative of perforation. **(b)** Sagittal CT image shows the spread of infection to subcutaneous fat around the port site (arrow) in the anterior abdominal wall.

to a gastric outlet obstruction. This complication is rare and usually results from inexperience on the part of the surgeon (23,24). Malposition of a gastric band can be easily detected on abdominal radiographs, as the band will have an abnormal lie and φ angle. In patients with this complication, the band is usually repositioned laparoscopically for continued management of obesity.

Gastric Perforation

Gastric perforation is rare, being seen in only 0.1%–0.8% of patients (22,25,26). This complication usually manifests in the early postoperative period with variable symptoms of infection ranging from fever to severe abdominal pain and hypotension.

At upper GI tract fluoroscopy, the observation of water-soluble contrast material outside the confines of the stomach in association with malposition of the gastric band clinches the diagnosis. Abdominal CT, preferably performed with water-soluble orally administered contrast material (15–20 mL), has the advantage of showing the extent of extraluminal and soft-tissue involvement. CT features that may be seen in a patient with gastric perforation after LAGB include penetration of the gastric wall by the band; extraluminal contrast material; free or loculated air in the peritoneal cavity (Figs 7, 8); and perigastric fluid, inflammation, and abscess formation (Figs 9, 10).

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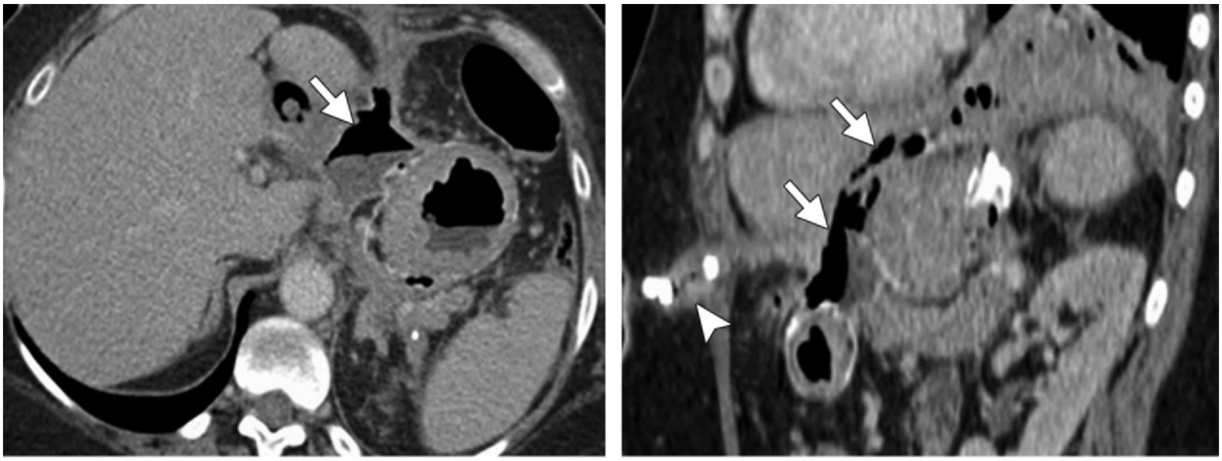
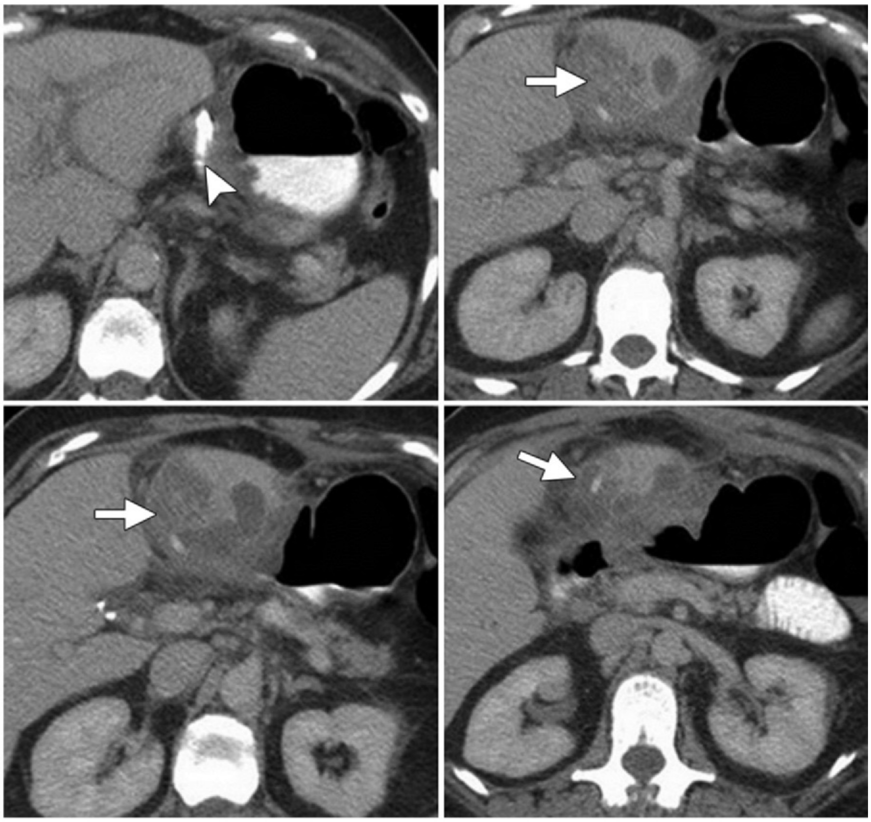


9a. 9b.



10.

Figures 9, 10. **(9)** Oral contrast material leakage and abscess at the gastric band site in a 61-year-old man with sepsis and abdominal pain a few years after undergoing LAGB. **(a)** Axial CT image shows an intraperitoneal abscess and perigastric fat stranding (arrow). **(b)** Sagittal CT image shows the extension of infection and inflammation (arrows) to the port site (arrowhead) in the anterior abdominal wall. **(10)** Hepatic abscess in a 52-year-old woman after LAGB. Axial abdominal CT images obtained at progressively lower levels (left to right, top to bottom) with both intravenous and oral contrast material show an ill-defined abscess (arrows) within the left hepatic lobe 2 months after placement of a gastric band (arrowhead).

In cases of gastric perforation, laparotomy is performed to remove the gastric band, débride infected soft tissue, and drain any abscess or fluid collection.

Pouch Dilatation

The imaging appearance previously described as “concentric dilatation” results from acute stomal stenosis. Possible causes of this finding include excessive tightening of the stoma, perigastric adhesions, and nutritional overload (15,21,23,24).

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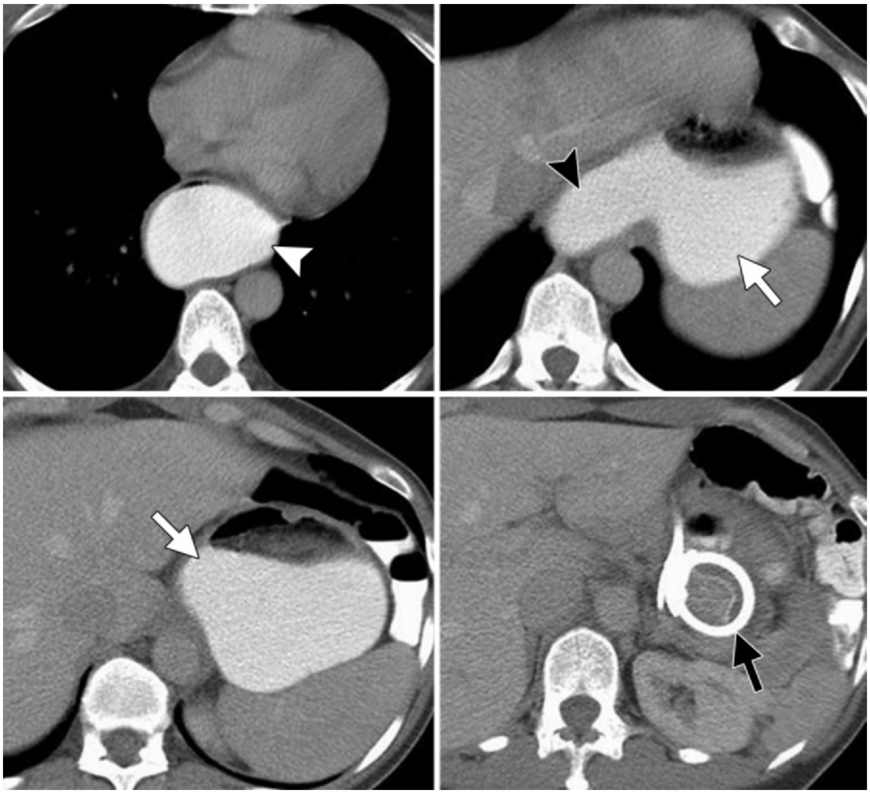


Figure 11. Band slippage with stomal obstruction in a 40-year-old woman with dysphagia and heartburn months after LAGB. Axial abdominal CT images obtained at progressively lower levels (left to right, top to bottom) with both intravenous and oral contrast material show eccentric pouch dilatation (white arrows) with marked dilatation of the distal esophagus (arrowheads). The band (black arrow) is located more inferiorly than expected.

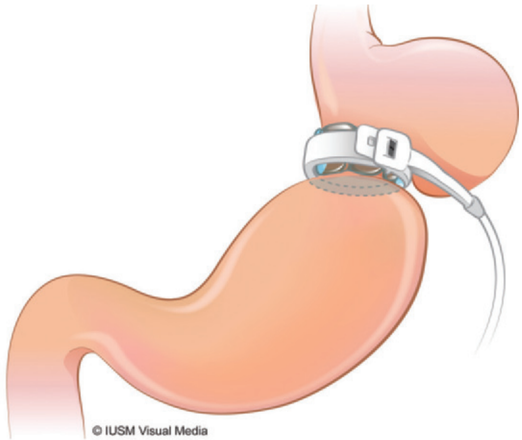
In the presence of this condition, the proximal gastric pouch appears enlarged and has a post-procedural capacity exceeding the norm of 15–20 mL. A tight stoma with delayed gastric emptying may also be observed. Axial herniation of the stomach, esophageal reflux, and esophageal dilatation may occur as associated delayed complications. Both fluoroscopy and CT with use of a water-soluble oral contrast medium allow visualization of these conditions (Fig 11).

In cases of sudden onset of stomal tightening, the obstruction is relieved by decompression of the port. Chronic dilatation results from excessive filling of the pouch and perigastric adhesions. If the band is in a good position, the patient may require counseling about appropriate nutritional intake. A follow-up fluoroscopic study should be performed 4–6 weeks later to determine whether the stomal stenosis has resolved and the gastric pouch is emptying as it should. Surgical intervention may be needed in cases of persistent symptoms, severe pouch dilatation, severe esophageal dilatation, and gastroesophageal reflux (25).

Gastric Band Slippage

Gastric band slippage is defined as herniation of the distal stomach upward from below the band. Slippage results in an abnormal band position and eccentric pouch dilatation (Figs 11, 12), and if this condition remains unaddressed, it may lead to chronic stomal stenosis, which has been observed in 4%–13% of patients (23,25,27). Slippage may occur in an anterior or posterior direction. Patients with this complication may present

Figure 12. **(a)** Drawing depicts anterior band slippage with a resultant increased φ angle and eccentric pouch dilatation. **(b)** AP abdominal radiograph obtained in a 49-year-old man with plateau in weight loss after LAGB shows a horizontal position of the gastric band (arrowhead) with a φ angle of 90° and a large, air-filled proximal pouch (arrow). **(c)** Upper GI tract fluoroscopic view confirms the presence of gastric band slippage (black arrowhead) with resultant eccentric dilatation of the pouch to a diameter of more than 4 cm (straight black arrow). The calibers of the gastroesophageal junction (curved arrow) and distal esophagus (white arrow) are normal. Evidence of pulmonary aspiration (white arrowhead) from severe gastroesophageal reflux is also seen.



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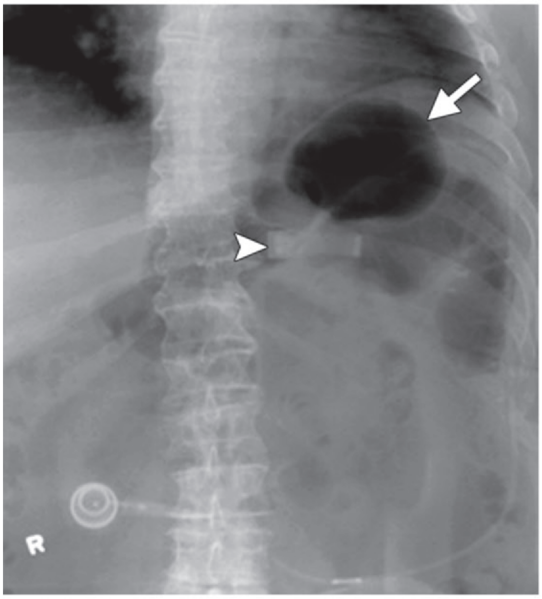

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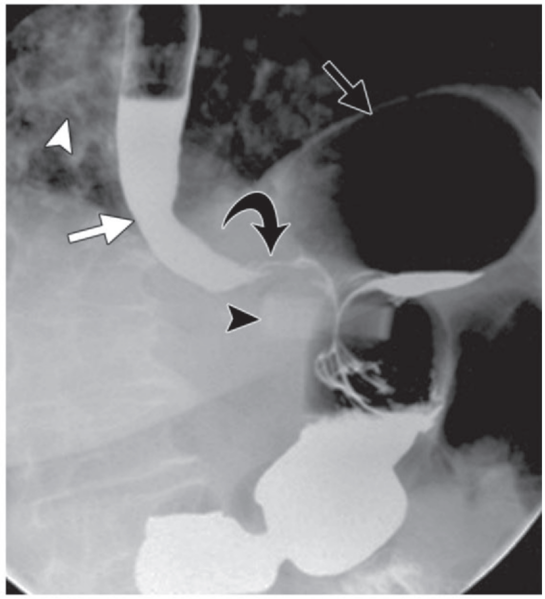


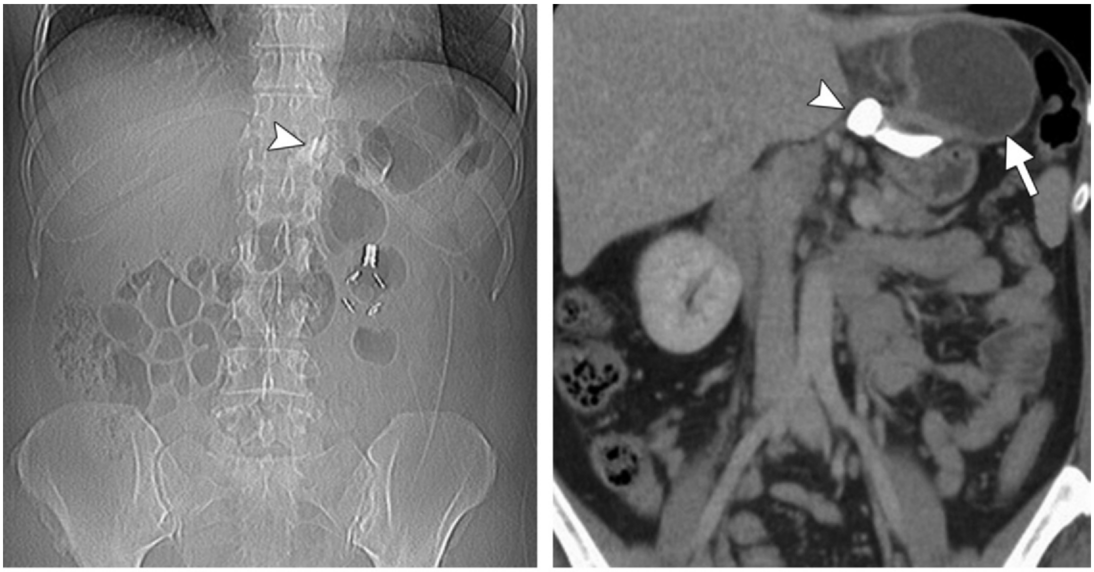
c.

with cessation of weight loss, severe gastroesophageal reflux, and nocturnal vomiting (24,25). When a slipped band leads to eccentric pouch dilatation and acute symptoms of stomal obstruction, associated gastric volvulus, gastric wall ischemia, or gastric perforation may occur (14,21). The diagnosis of intermittent band slippage is challenging: A patient may present with intermittent obstructions when the band slips into an abnormal position after the pouch is filled. However, as the pouch empties and the system decompresses, the band resumes its normal position and the obstruction resolves (15,21).

Herniation of the posterior and inferior portions of the distal stomach characterizes posterior slippage of the gastric band. In various studies, this condition has been associated with transbursal band placement (4,20,21). A newer technique of LAGB implantation involves band placement higher in the hepatogastric ligament without violation of the lesser sac so that the band is distant from the peristaltic stomach (15,19). Therefore, posterior band slippage is uncommon (13).

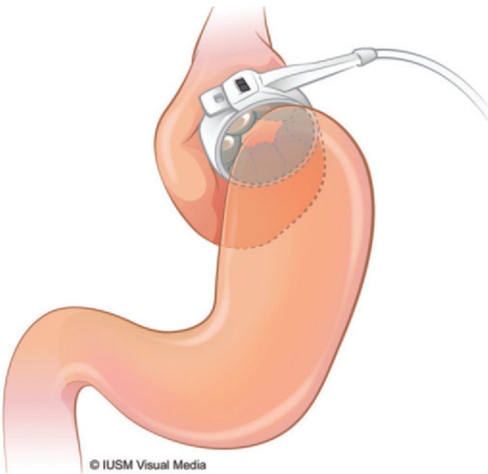
Teaching Point

Herniation of the anterior and superior portions of the distal stomach characterizes anterior slippage of the gastric band. The band is pushed downward over the anterior stomach because of increased pressure in the proximal pouch. Unlike posterior slippage, this event is still commonly encountered, most likely as a result of weakened serosal stitches on the gastric band (21,28). In



a. b.

Figure 13. Anterior slippage of the gastric band in a 56-year-old woman with lack of weight loss after LAGB. **(a)** AP abdominal radiograph shows leftward rotation of the gastric band (arrowhead) with a φ angle of more than 90°. **(b)** Coronal CT image shows a horizontal position of the band (arrowhead) and an eccentrically dilated pouch (arrow), findings that help confirm the diagnosis.



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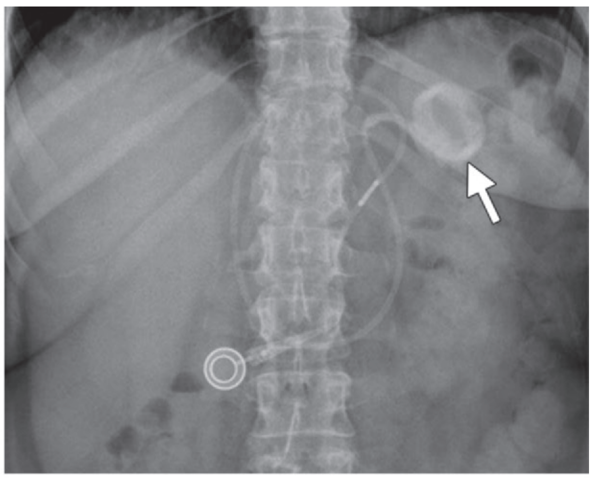


15.

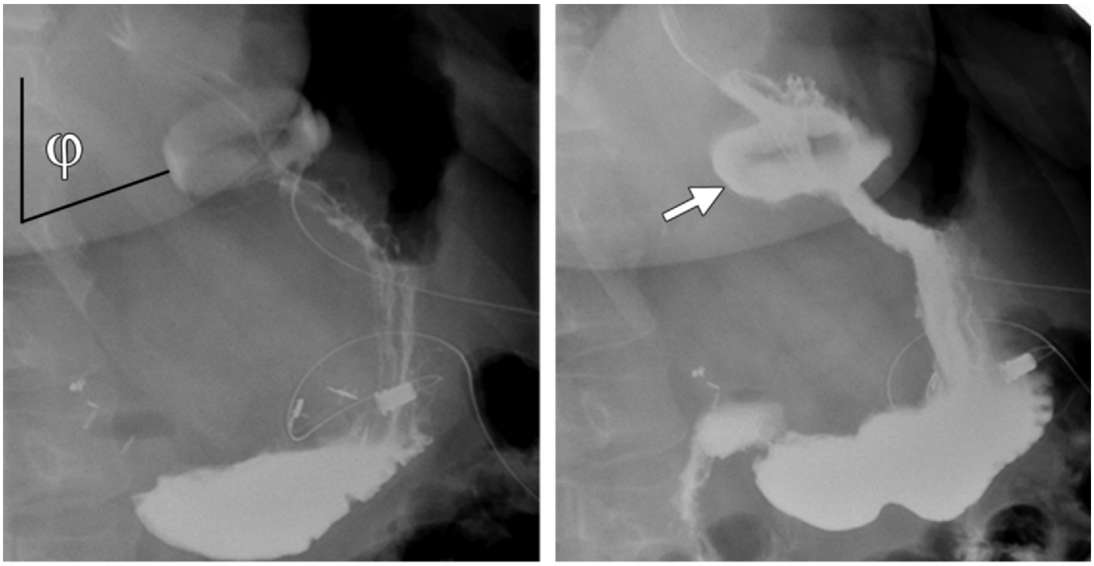
Figures 14, 15. **(14)** Drawing depicts the gastric band position that produces the O sign, an imaging feature associated with posterior band slippage and proximal herniation of the stomach. **(15)** AP abdominal radiograph shows a gastric band (arrow) positioned en face (the O sign), a finding indicative of band slippage, usually in the posterior direction.

the presence of anterior gastric band slippage, a progressive rotation of the band, with a φ angle of more than 58°, is seen on abdominal radiographs (Figs 12, 13). Eccentric pouch dilatation and an air-fluid level also may be seen.

The gastric band should not be seen *en face*: Pieroni et al have described the “O sign,” an ovoid or O-shaped appearance of the band, as a characteristic radiographic feature of band slippage (29). This appearance is usually associated with band slippage in the posterior direction (Figs 14, 15).

Teaching Point

RadioGraphics



a. b.

Figure 16. Intragastric band erosion in a 42-year-old man with abdominal pain 3 months after LAGB. **(a)** Initial fluoroscopic view of the upper GI tract shows a φ angle greater than 60°, a finding indicative of an abnormal position of the gastric band. **(b)** Delayed upper GI tract fluoroscopic view shows a progressive increase in opacification of the gastric band (arrow), with no intraperitoneal leakage of contrast material. These findings are suggestive of incomplete intragastric erosion. The diagnosis was confirmed and the band removed at endoscopy.

At upper GI tract fluoroscopy performed with a water-soluble oral contrast material, abnormal positioning of the gastric band with eccentric dilatation of the gastric pouch to a maximal diameter of more than 4 cm is observed. Depending on the degree of stomal obstruction, delayed gastric emptying and esophageal dilatation may also be present.

In cases of gastric band slippage with severe obstruction of the stoma leading to gastric outlet symptoms, immediate band decompression can relieve symptoms. However, laparoscopic fixation of the band to its original position is the optimal surgical step (21). In cases of posterior band slippage, laparoscopic band replacement in a suprabursal position should be performed.

Intragastric Erosion

This delayed complication has been observed in 0.3% to 14% of patients in various series (30–34). (The wide range in the percentages of patients affected is probably due to variation in the follow-up periods in different series.) Intragastric erosion may be partial or complete. Its causes include small gastric wall injuries incurred during band placement, overdistention of the band with resultant gastric wall ischemia, band site infection, and inflammatory reaction (35–37). Adhesions from widespread dissection during band placement and the use of nonsteroidal anti-inflammatory drugs also may contribute to erosion (35–37). The gastric band may sink into a minor tear in the gastric wall and eventually erode through it, into the gastric lumen.

Intragastric band erosion can be a chronic, insidious process; in one study, nearly half (46%) of patients affected by this complication were asymptomatic (36). Patients may present with nonspecific abdominal complaints such as vague epigastric pain, cessation of weight loss, or hematemesis, or turbid fluid may have been aspirated from the port. Recurrent port-site infections or inability to inflate the port also may be a sign of intragastric erosion (22,36,38).

On radiographs, an abnormal position of the band is seen (15,38). If a comparison with previously acquired radiographs shows progressive

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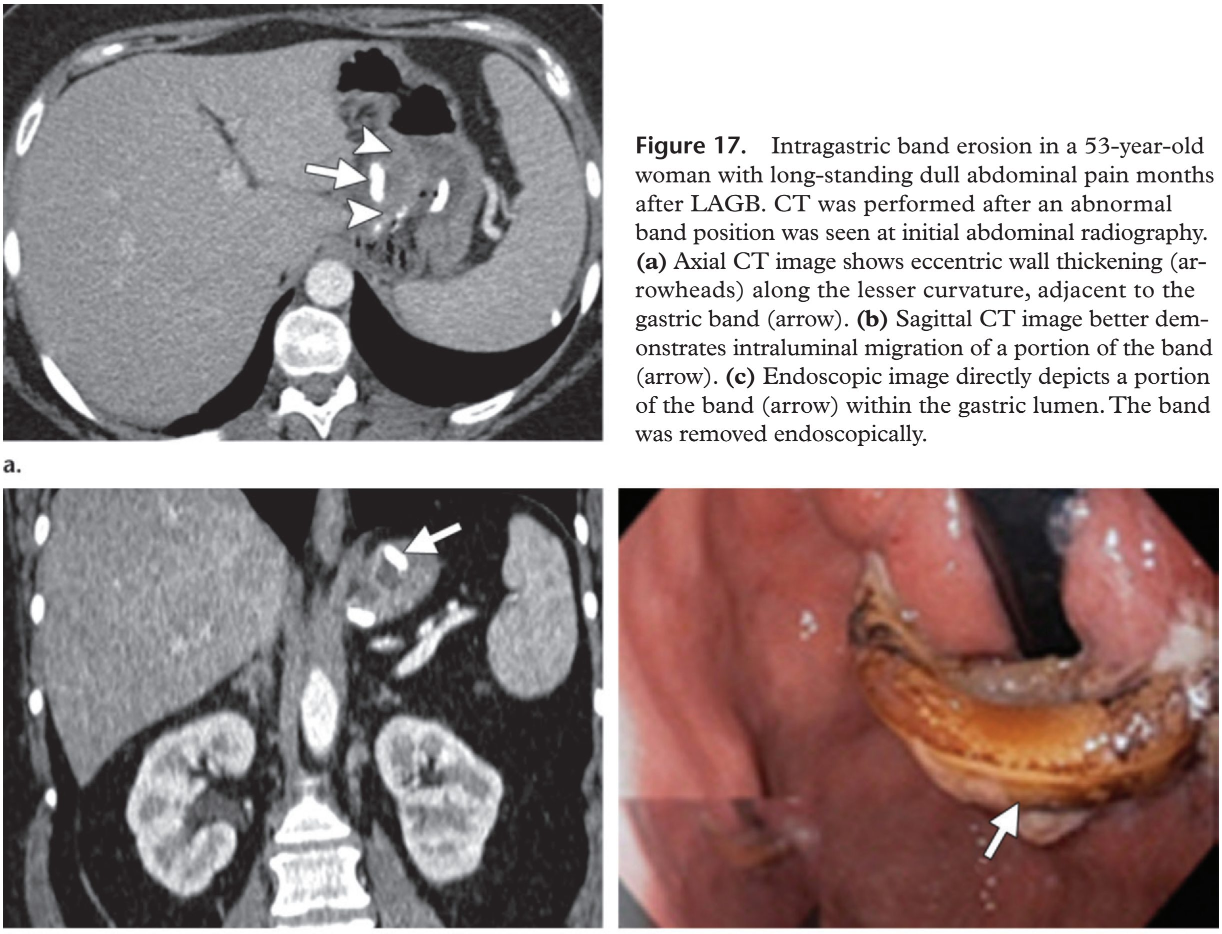

a. b. c.

Figure 17. Intragastric band erosion in a 53-year-old woman with long-standing dull abdominal pain months after LAGB. CT was performed after an abnormal band position was seen at initial abdominal radiography. **(a)** Axial CT image shows eccentric wall thickening (arrowheads) along the lesser curvature, adjacent to the gastric band (arrow). **(b)** Sagittal CT image better demonstrates intraluminal migration of a portion of the band (arrow). **(c)** Endoscopic image directly depicts a portion of the band (arrow) within the gastric lumen. The band was removed endoscopically.

migration of the band over time to an abnormal position, the cause may well be intragastric erosion. Findings at fluoroscopy performed with a water-soluble oral contrast medium may be normal at an early stage of erosion. However, at later stages, contrast material is seen surrounding the eroded portion of the band that lies in the gastric lumen (Fig 16).

Because patients with intragastric erosion may present with nonemergent symptoms, the condition may be detected incidentally at CT performed for other reasons. However, when CT is requested because the presence of intragastric erosion is suspected, the use of dilute water-soluble contrast material is helpful for detecting complete erosion. When erosion is incomplete (ie, the band has only partially eroded through the gastric wall), it is especially difficult to detect. A review of multiplanar images can be helpful for identifying sites of gastric erosion (Figs 17, 18). Direct visualization of any portion of the band in continuity with the gastric lumen at upper GI tract endoscopy is the reference standard for definitive diagnosis.

After the diagnosis is established, removal of the band is mandatory to avoid further erosion with the likely possibilities of resultant abscess formation, peritonitis, and spreading infection along the connector tube to the port. The band may be removed endoscopically or laparoscopically (39). Within a week after the band is removed, follow-up upper GI tract fluoroscopy with the use of a water-soluble oral contrast material should be performed to determine whether leakage is ongoing at the site of erosion.

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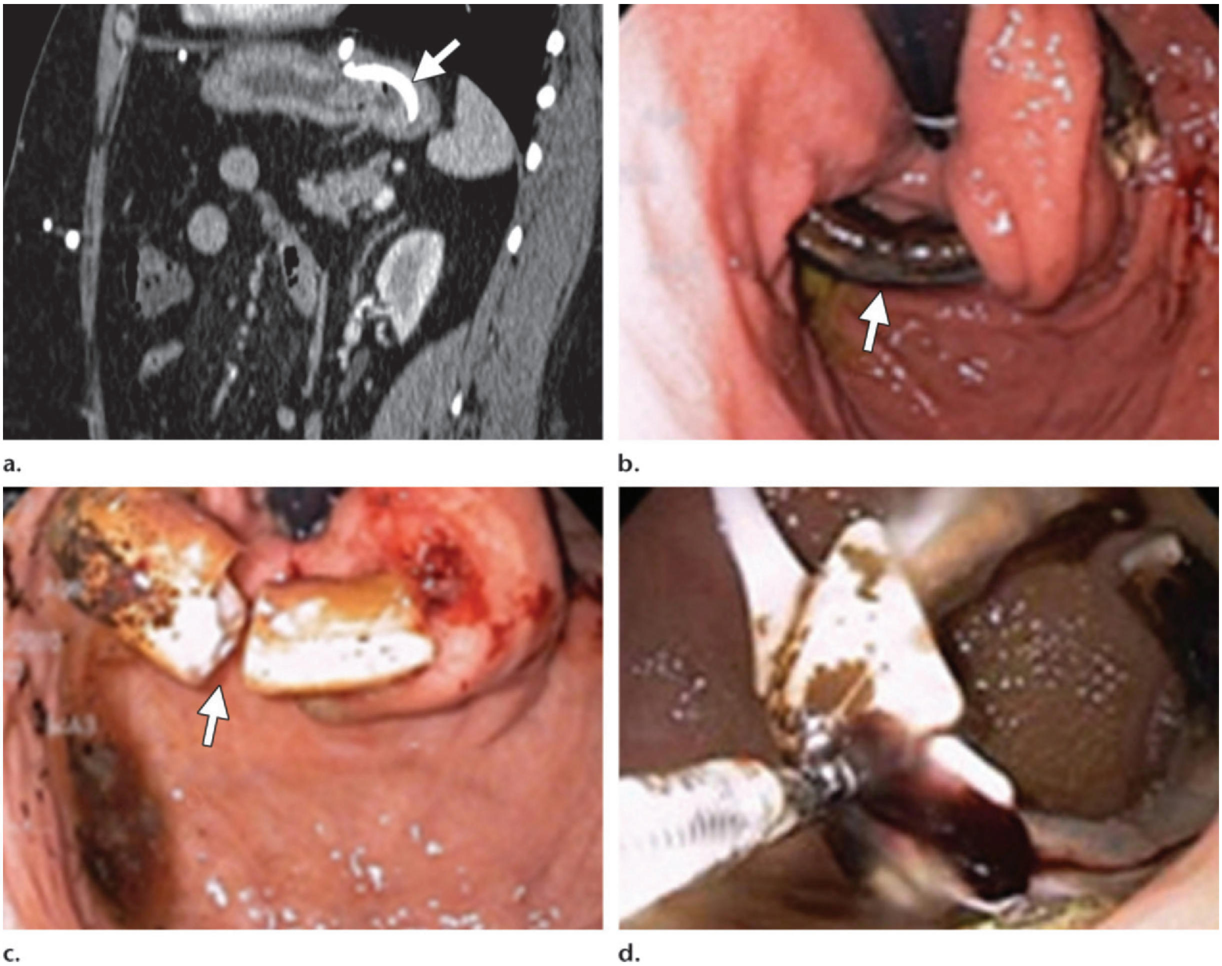

Figure 18. Intragastric band erosion in a 67-year-old man with dull abdominal pain 1 year after LAGB. Although abdominal radiography showed the gastric band in a normal position, CT was performed because of worsening symptoms. **(a)** Sagittal CT image shows that a small portion of the band (arrow) has eroded the gastric wall. This appearance should lead to a careful review of all reformatted CT images to determine whether any portion of the band has penetrated into the lumen. **(b)** Endoscopic image directly depicts a portion of the band (arrow) within the lumen. **(c, d)** Endoscopic views obtained during band removal show cut pieces of the band (arrow in **c**), which were extracted with an endoscopic snare **(d)**.

Esophageal Dilatation and Dysmotility

Dysmotility occurs before esophageal dilatation and aperistalsis develop (15,19). Other contributors to esophageal dilatation are preexisting insufficiency of the gastroesophageal sphincter, an insufficient change in dietary habits after LAGB, proximal pouch dilatation, and stomal narrowing (15,40). Gastroesophageal reflux, esophagitis, and aspiration are secondary complications that may result from esophageal dilatation and dysmotility.

Patients may have symptoms of mild dysphagia or gastroesophageal reflux early or late in the postprocedural period. An upper GI tract examination with the use of a water-soluble oral contrast medium may demonstrate esophageal dilatation with reduced or absent peristalsis, conditions similar to those seen in achalasia. This complication is potentially reversible with band removal (41). However, underlying anatomic factors (eg, band slippage, inappropriate dietary intake, stenosis of the stoma) that could cause proximal pouch dilatation may be sought and treated first.

Connector Tube– and Port-Related Complications

Reported system-related complications include tube disconnection, port-site infection, peritoneal adhesions leading to bowel obstruction, and gastric volvulus, the last of which has been reported to occur with a frequency of 0%–7% in different patient series (21,23,25,27).

Tube Disconnection and Leakage.—Patients with this complication present with reversal of weight loss or the inability to eat after the procedure, both problems that may result from a malfunctioning tube or port or from disconnection of the

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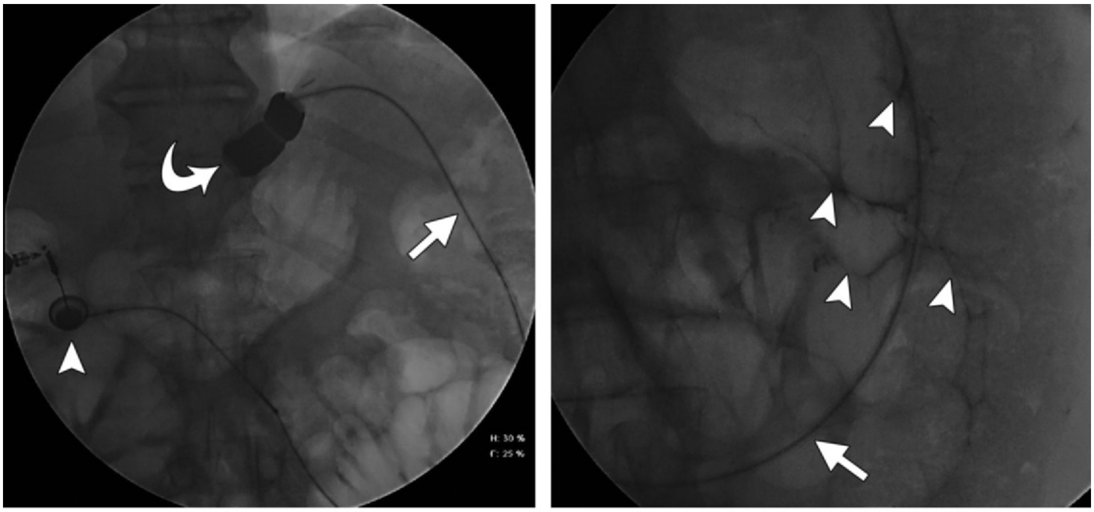

a. b.

Figure 19. Leakage around the connector tube in a 67-year-old man with dull abdominal pain 3 years after LAGB. A scout radiograph (not shown) demonstrated the band was in the correct position. **(a)** Initial upper GI tract fluoroscopic image shows uniform band inflation (curved arrow) and continuity between the port (arrowhead) and the connector tube (straight arrow). Contrast material outlining the tube is seen in the left mid abdomen, a finding suggestive of leakage. **(b)** Magnified view of the left abdomen shows leaked contrast material outlining bowel loops (arrowheads) that surround the connector tube (arrow), but the site of leakage could not be determined. The LAGB system was subsequently replaced.

Figure 20. Local infection in a 69-year-old woman with pain, redness, and swelling at the port site, leading to difficulty in accessing the port. Axial CT image shows a low-attenuation fluid collection (arrow) with adjacent soft-tissue stranding along the port *(P)*, findings suggestive of an abscess. No intraperitoneal extension of inflammation is seen along the connector tube *(T)*. The abscess was treated with surgical débridement, and the port was replaced.

tube at the junction with the port or the band. Port manipulation due to trauma or patient discomfort also may be a causative factor.

Obvious disconnection of the tube is visible on radiographs. However, fluoroscopy performed with the injection of 5 mL of a water-soluble nonionic contrast medium through the port can better demonstrate the site of leakage (Fig 19) as well as asymmetric and nonuniform band inflation.

A disconnected tube or leaking port should be surgically removed and replaced.

Port-Site Infection.—Port-site infections manifest much as other subcutaneous infections do, with swelling, warmth, erythema, and fever. If the infection is detected at an early stage, oral antibiotic therapy may suffice (15,21,25). However, the patient's body habitus may make the diagnosis of early-stage infection difficult. If it remains undetected, a superficial infection can progress to local abscess formation and spread along the connector tube into the peritoneum and stomach. Early postoperative port-site infections (ie, occurring within 1 month of surgery) most likely represent surgical site infections. Port-site infections that develop at more remote time points often are related to intragastric band erosion. Development of a spontaneous port-site infection months or years after band placement should prompt upper GI tract endoscopy to allow detection of erosion.

Ultrasonography can be helpful for visualizing an abscess in subcutaneous tissues around the port. However, CT can delineate the local extent of infection as well as its distant spread into the peritoneum or stomach (Fig 20).

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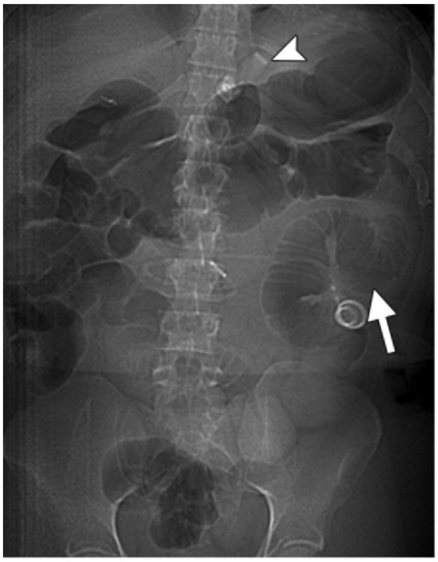
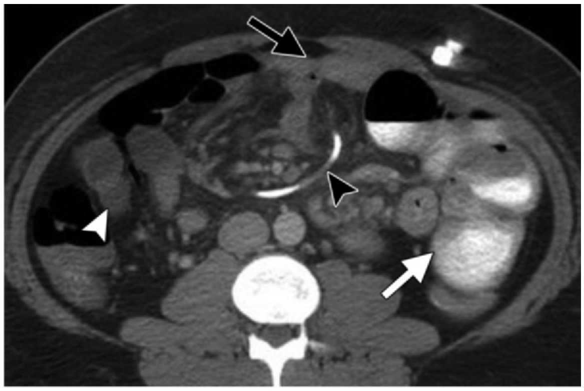
Figure 21. Small bowel obstruction in a 58-year-old man with a sudden onset of abdominal pain several years after LAGB. **(a)** AP abdominal radiograph shows distended loops of proximal small bowel (arrow), findings suggestive of obstruction. The gastric band (arrowhead) is in a normal position, and the φ angle is normal. **(b, c)** Axial CT images (**b** at a higher level than **c**) show distended small bowel loops (white arrows) with a transition point (black arrow) in the anterior abdomen around the connector tube (black arrowhead). Distal small bowel (white arrowhead) is not distended. Exploratory laparotomy showed a small bowel obstruction due to dense intraperitoneal adhesions around the connector tube.



a.



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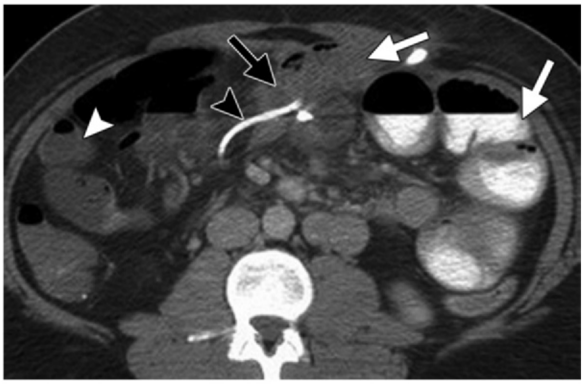

c.

Early port-site infections require immediate local surgical débridement with oral antibiotic therapy. In more advanced infections, laparoscopic tube transection and port replacement may be performed, followed by intravenous antibiotic therapy. When port-site infections occur in conjunction with band erosion, the entire LAGB system (including port, tube, and band) must be explanted, usually at laparoscopic surgery, and the wound treated with local débridement and systemic antibiotic therapy.

Small Bowel Obstruction.—Inflammatory adhesions may form around the connector tube within the peritoneum. Such adhesions, which are thought to result from an immune reaction to the foreign body, may lead to bowel obstruction and bowel volvulus (15). Such adhesions are the most common cause of small bowel obstructions that occur after LAGB procedures. Patients typically present with acute abdominal pain and distention.

Abdominal CT scans or radiographs depict small bowel obstructions, and CT scans may show peritubal soft tissue and adhesions forming the leading point of an obstruction (Fig 21). Adhesiolysis is typically performed to relieve the bowel obstruction, and the connector tube is replaced.

Conclusions

LAGB is a well-established, minimally invasive treatment for morbid obesity. Imaging and clinical assessments are important for postoperative evaluation of patients as well as for the detection of potential complications. With improvements in surgical techniques and expertise, the number of patients undergoing LAGB continues to increase and the rate of complications to decrease. It is important to note that patients with delayed complications of LAGB may present with nonspecific abdominal symptoms, and the first opportunity to detect such symptoms may occur at imaging performed for those symptoms or for other indications. For timely and appropriate management of these complications, it is imperative that radiologists, regardless of their subspecialty, be familiar with the normal and abnormal imaging appearances of gastric bands and related complications. The roles of various imaging modalities and the typical imaging features seen in

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Table 2
Usefulness of Various Imaging Modalities for Detecting Complications of LAGB

Complication	Radiography	UGI Fluoro	Oral Contrast Material–enhanced CT	Port Fluoro	US	Endoscopy	Diagnostic Findings
Band malposition	+	NA	NA	NA	NA	NA	Abnormal φ angle
Gastric perforation	±	++	++	NA	NA	NA	Free extraluminal oral contrast materials, free or loculated intraperitoneal air
Gastric perforation with perigastric abscess formation	±	++	+++	NA	NA	NA	Localized extraluminal oral contrast material, peripherally enhancing fluid collection at CT
Concentric pouch dilatation	NA	++	+	NA	NA	NA	Enlarged proximal pouch with tight stoma and delayed emptying, normal band position
Band slippage	+	++	++	NA	NA	NA	Abnormal band position (increased φ angle, O sign), eccentric enlargement of the proximal pouch
Intragastric band erosion	±	++	+	NA	NA	+++	Progressive nonuniform opacification due to oral contrast material leakage around band, intragastric migration of band on reformatted CT images
Esophageal dilatation and dysmotility	NA	++	NA	NA	NA	NA	Altered peristalsis, esophageal dilatation at UGI examination
Tube disconnection and leakage	+	NA	+	++	NA	NA	Discontinuity between port, tube, and band at radiography and CT, leakage of contrast material from tube at port fluoroscopy
Port-site infection	NA	NA	++	NA	+	+++	Peripherally enhancing fluid collection around port, endoscopy recommended to detect intragastric erosion
Small bowel obstruction	+	+	+++	NA	NA	NA	Point of transition adjacent to the connector tube at CT

Note.—The symbols +, ++, and +++ indicate slight, moderate, and markedly increased accuracy for detection of the complication specified, and ± indicates little or no effect on accuracy. Fluoro = fluoroscopy, NA = not applicable, UGI = upper GI tract.

the presence of a specific complication of LAGB are summarized in Table 2.

***Disclosures of Potential Conflicts of Interest.*—K.S.:** *Related financial activities:* none. *Other financial activities:* consultant for Repligen.

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Laparoscopic Adjustable Gastric Banding: What Radiologists Need to Know

Sushilkumar K. Sonavane, MD • Christine O. Menias, MD • Kartikeya P. Kantawala, MD, DMRD • Alampady K. Shanbhogue, MD • Srinivasa R. Prasad, MD • John C. Eagon, MD • Kumaresan Sandrasegaran, MD

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Page 1162
With the pars flaccida technique, the gastric band is placed within 2 cm of the gastroesophageal junction, without penetrating the lesser sac. More distal placement of the gastric band with the perigastric technique is associated with a higher band slippage rate.

Page 1164
On AP abdominal radiographs, the superior angle formed by the longitudinal axis of the gastric band and the spinal column, which is referred to as the φ (phi) angle, should be between 4° and 58°. The gastric band should be positioned approximately 5 cm below the left hemidiaphragm and should have a rectangular appearance on AP radiographs because its anterior and posterior aspects are superimposed.

Page 1164
When distended by a volume of 15–20 mL of the oral contrast agent, the proximal pouch should measure less than 4 cm at its widest diameter, and the stomal diameter should be less than 4 mm. The pouch should begin emptying almost immediately, and emptying should be nearly complete within 15–20 minutes.

Page 1170
Herniation of the posterior and inferior portions of the distal stomach characterizes posterior slippage of the gastric band. In various studies, this condition has been associated with transbursal band placement. A newer technique of LAGB [laparoscopic adjustable gastric band] implantation involves band placement higher in the hepatogastric ligament without violation of the lesser sac so that the band is distant from the peristaltic stomach. Therefore, posterior band slippage is uncommon.

Page 1171
The gastric band should not be seen *en face*: Pieroni et al have described the “O sign,” an ovoid or O-shaped appearance of the band, as a characteristic radiographic feature of band slippage. This appearance is usually associated with band slippage in the posterior direction.