Imaging Findings of Successful and Failed Fundoplication[1]

Alberto I. Carbo, MD
Roger H. Kim, MD
Thomas Gates, MD
Horacio R. D'Agostino, MD

Abbreviations: GERD = gastroesophageal reflux disease, LES = lower esophageal sphincter

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[1]From the Departments of Radiology (A.I.C., T.G., H.R.D.) and Surgery (R.H.K.), Louisiana State University Health Sciences Center, 1501 Kings Hwy, Shreveport, LA 71103. Presented as an education exhibit at the 2012 RSNA Annual Meeting. Received October 14, 2013; revision requested January 31, 2014, and received March 4; accepted May 21. For this journal-based SA-CME activity, the author H.R.D. has provided disclosures (see p 1883); all other authors, the editor, and the reviewers have disclosed no relevant relationships. **Address correspondence to** A.I.C. (e-mail: *acarbo@lsuhsc.edu*).

SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Describe the mechanisms that prevent gastroesophageal reflux and esophageal damage.
- Discuss the indications for and techniques of Nissen fundoplication.
- Recognize radiologic findings of various types of failed fundoplication.

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TEACHING POINTS

See last page

Postoperative imaging findings contribute to the diagnosis of successful and failed fundoplication procedures. Gastroesophageal reflux disease, a common illness in the United States, is primarily treated medically but may require surgery if there are persistent symptoms or reflux complications despite medical treatment. Laparoscopic Nissen fundoplication has become the most used and successful surgical antireflux procedure since its introduction in 1991. Radiologists should understand the anatomy of the esophagogastric junction, antireflux and esophageal protective mechanisms, and preoperative radiologic findings that contribute to selection of the surgical technique, as well as the most commonly used antireflux operations and their indications. Barium examination and computed tomography of the thorax and abdomen play an important role in the follow-up of patients with gastric fundoplication, including evaluation of surgical effectiveness and detection and characterization of postoperative complications. Failed fundoplications are classified into six types: tight Nissen, incompetent repair, disruption of the wrap, stomach slippage above the diaphragm, slipped Nissen, and transdiaphragmatic wrap herniation. Classification is based on radiologic visualization of the obstructed esophageal lumen, recurrence of gastroesophageal reflux, integrity and location of the gastric wrap, stomach slippage, and recurrence of hiatal hernia. Imaging findings are useful in detecting complications, providing anatomic information to identify the cause of surgical failure, and selecting appropriate medical or surgical management.

Introduction

This article reviews imaging findings at barium examination and computed tomography (CT) used to evaluate patients before antireflux surgery and after successful and failed fundoplication procedures. A brief description of the anatomy of the gastroesophageal

junction and antireflux and esophageal protective mechanisms is incorporated. Additional topics include the indications, objectives, and techniques for surgical antireflux procedures and the indications for a second surgery in patients with an unsuccessful repair.

Gastroesophageal reflux disease (GERD) is a common illness in America. An estimated 44% of the population experiences heartburn at least once a month, and 18% of those take some form of antireflux medication routinely. Nineteen percent of patients who undergo endoscopy for upper gastrointestinal symptoms have evidence of esophagitis (1). GERD is primarily treated medically with acid-reducing agents and lifestyle changes. Patients who have persistent symptoms despite medical treatment or who suffer from GERD complications may benefit from surgery.

Fundoplication surgery, either open or laparoscopic, is a safe and effective method for resolving GERD symptoms and preventing disease complications. The technique has a 5-year follow-up success rate of 86%–96%. However, 2.8% of patients will require redo fundoplication (2). In cases of failed fundoplication, barium examination of the upper gastrointestinal tract and CT assist in evaluating the postsurgical results. Imaging provides information to help the physician understand the mechanism of failure and its functional consequences, determine whether further surgery is necessary, and select the appropriate surgical procedure.

Teaching Point

Antireflux and Esophageal Protective Mechanisms

The integrity of the esophageal mucosa requires a balance between esophageal mucosal defense mechanisms and damaging forces (ie, the duration and potency of reflux). When this balance is impaired, an excessive diffusion of hydrogen ions into the mucosa leads to cellular acidification, inflammation, and necrosis.

The lower esophageal sphincter (LES) consists of a thickening of the circular muscular layer in the distal 5 cm of the esophagus (Fig 1). Contraction of the LES is the most important of the multiple mechanisms that prevent gastroesophageal reflux (1). Under conditions of straining, two additional mechanisms help prevent reflux: the extrinsic compression of the diaphragmatic crura on the distal esophagus and intraabdominal pressure on the abdominal esophagus.

Mechanisms that prevent damage to the esophageal mucosa caused by gastroesophageal reflux include neutralization of the acid reflux material by salivary secretions and secondary contractions of the esophagus to clear the reflux. Esophageal tertiary contractions are nonpropulsive and thus do not contribute to clearance of the reflux material. The tight junctions of the superficial layer of the esophageal mucosa and its regenerative capacity increase the resistance to transmural ion penetration and damage. In addition, secretion of bicarbonate and phospholipids into the surface mucus by the esophageal submucosal glands increases mucosal resistance to injury. Prolonged injury caused by gastroesophageal reflux may lead to replacement of the esophageal squamous mucosa by metaplastic columnar epithelium (Barrett syndrome) and adenocarcinoma (1,3).

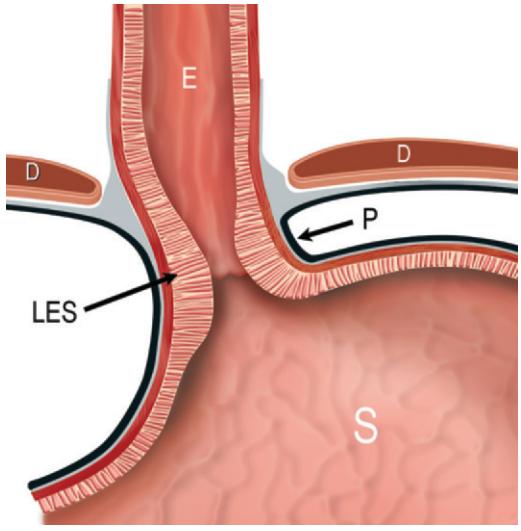


Figure 1. Anatomy of the esophagogastric junction. Drawing shows the antireflux mechanisms of the LES and diaphragmatic crura. *D* = diaphragm, *E* = esophagus, *P* = peritoneum, *S* = stomach.

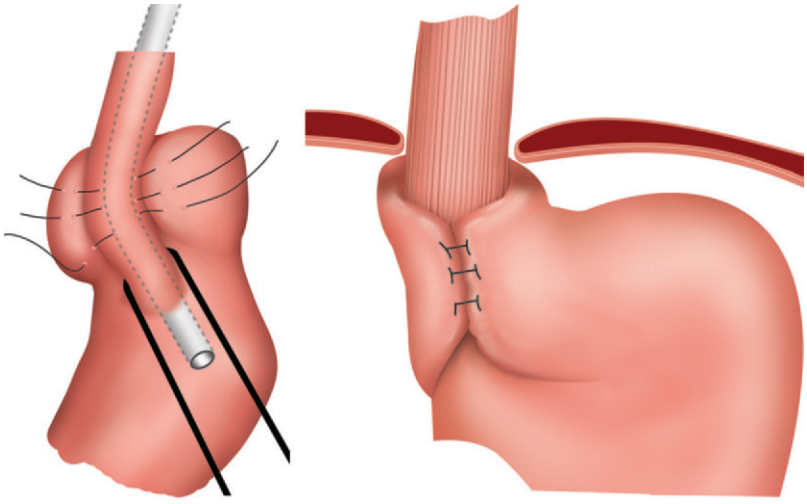
Radiologic Evaluation

Preoperative evaluation of patients with GERD includes videoesophagography or an upper gastrointestinal series. The radiologic examination includes double-contrast gastrointestinal radiography. The barium examination is performed to diagnose a hiatal hernia that may need to be reduced or a shortened esophagus that may necessitate a lengthening procedure. In addition, the study may help visualize reflux and detect complications such as esophageal ulcerations and strictures. The imaging examination should include an evaluation of the swallowing mechanism to diagnose abnormalities associated with chronic reflux, such as cricopharyngeal dysfunction, and assessment of esophageal function to identify esophageal motility disorders that may require a different surgical technique (3,4).

Teaching Point

Indications for Antireflux Surgery

GERD is a common condition that can be controlled in most patients by use of medical



a. b.

Figure 2. Nissen fundoplication technique. Drawings show a bougie dilator inserted into the esophageal lumen and sutures positioned between the gastric wrap and esophageal wall **(a)** and the final wrapping of the stomach around the distal esophagus **(b)**.

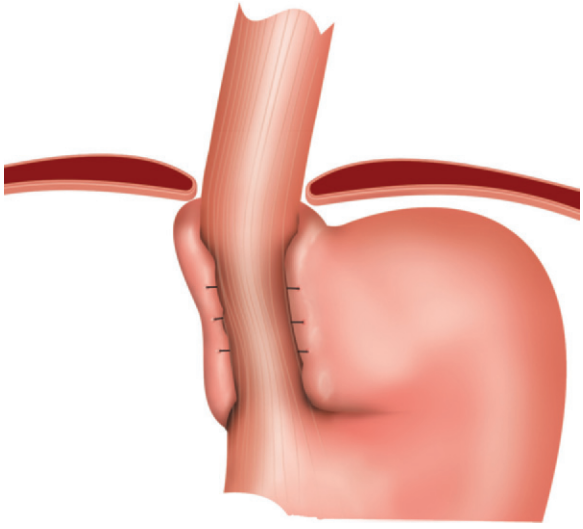


Figure 3. Toupet fundoplication technique. Drawing shows a partial (270°) fundal wrap around the distal esophagus.

therapy with acid-reducing agents and lifestyle modifications. Patients with GERD who do not improve with medical treatment may benefit from surgery. Indications for antireflux surgery include complications such as asthma and aspiration pneumonia, persistent esophageal ulcerations and strictures, Barrett syndrome, and medication intolerance (1,4).

Surgical Objectives and Techniques

Teaching Point

Surgical antireflux techniques are used to correct anatomic and functional abnormalities that cause reflux. These rectifications include reduction of a hiatal hernia by returning the LES to the abdomen and re-creation of the esophagogastric angle to act as a nonrefluxing valve. Construction of a gastric wrap around the distal esophagus supports the LES in place and increases its resting pressure. Finally, approximation of the diaphragmatic crura helps hold the fundoplication wrap in the abdomen and assists the sphincter in creating an adequate pressure (1,4,5).

Nissen fundoplication is the most commonly performed antireflux procedure for treatment of GERD. The laparoscopic technique was introduced in 1991 (2). The technique consists of mobilization and return of the distal esophagus (3–4 cm) to the abdominal cavity without tension (1,4,5). The upper portion of the stomach is liberated of all attachments, wrapped 360° around the circumference of the esophagus, and sutured together anteriorly. To prevent the creation of a "too-tight" fundoplication wrap and subsequent obstructive symptoms, the wrap is performed over the esophagus with use of a luminal large-bore dilator (Fig 2). When a hiatal hernia is present, the diaphragmatic hiatus is repaired by approximating and sewing the crural limbs behind the esophagus. If there is an insufficient length of infradiaphragmatic esophagus to complete the wrap, a lengthening technique such as a Collis gastroplasty may be performed (1,4,5).

The Toupet technique is one of the multiple variations of Nissen fundoplication. It consists of a partial (270°) posterior wrapping of the distal esophagus. The fundoplication wrap is attached to the anterior esophageal wall and the diaphragmatic hiatus (Fig 3). Because of the incomplete wrapping of the esophagus, this technique is used

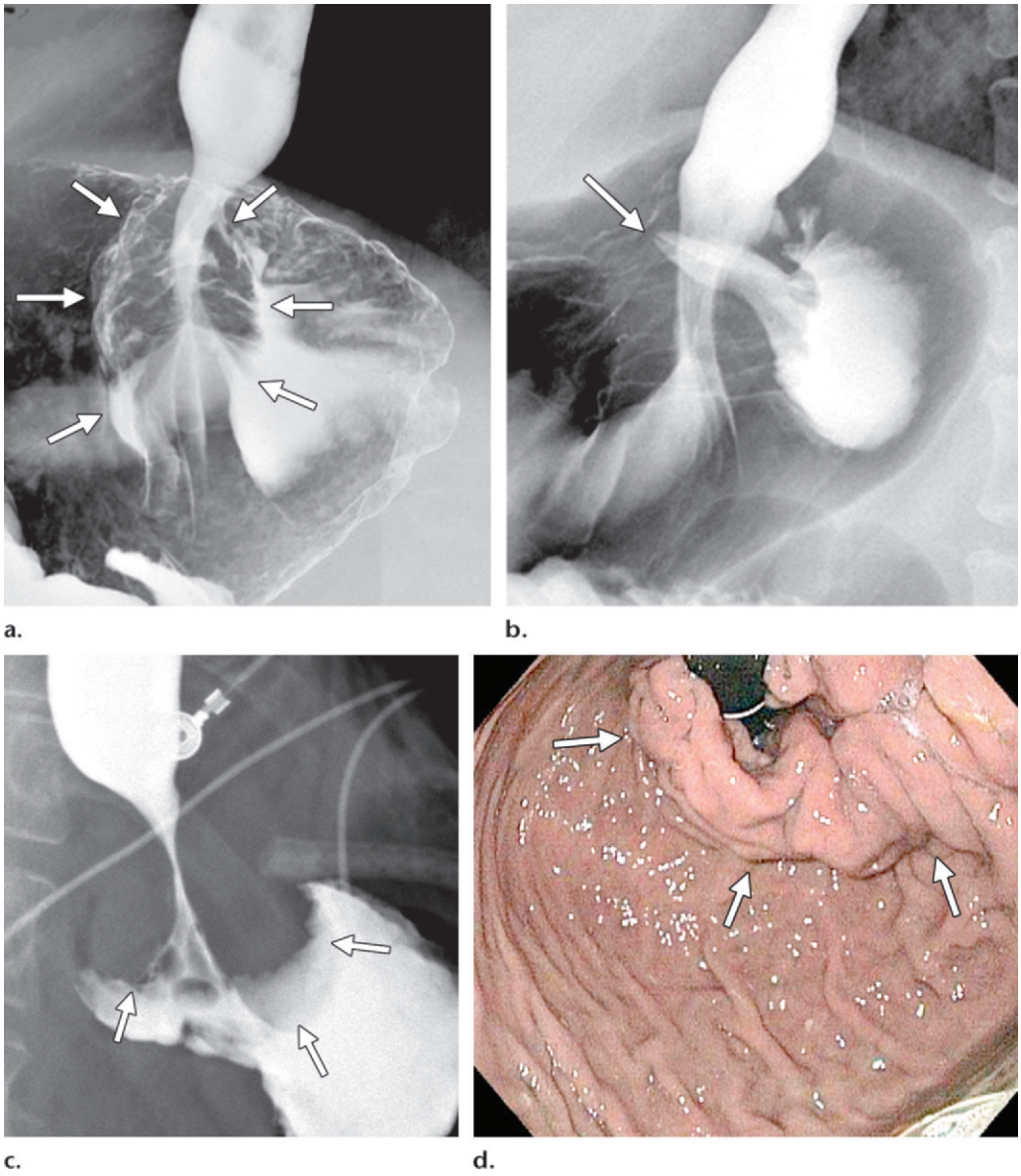


Figure 4. Imaging appearance after fundoplication. **(a)** Image from a double-contrast barium study shows a smooth filling defect in the gastric fundus (arrows) surrounding the distally curved esophagus. **(b)** Image from a double-contrast barium study shows the lumen of a wrap completely filled with barium (arrow), a finding seen occasionally. **(c)** Image from an immediate postoperative single-contrast barium study in a pediatric patient shows the distal esophagus surrounded by a large fundal defect that resembles an inverted "3" (arrows). **(d)** Retroverted endoscopic image of the esophagogastric junction shows a protruded wrap surrounding the cardia (arrows).

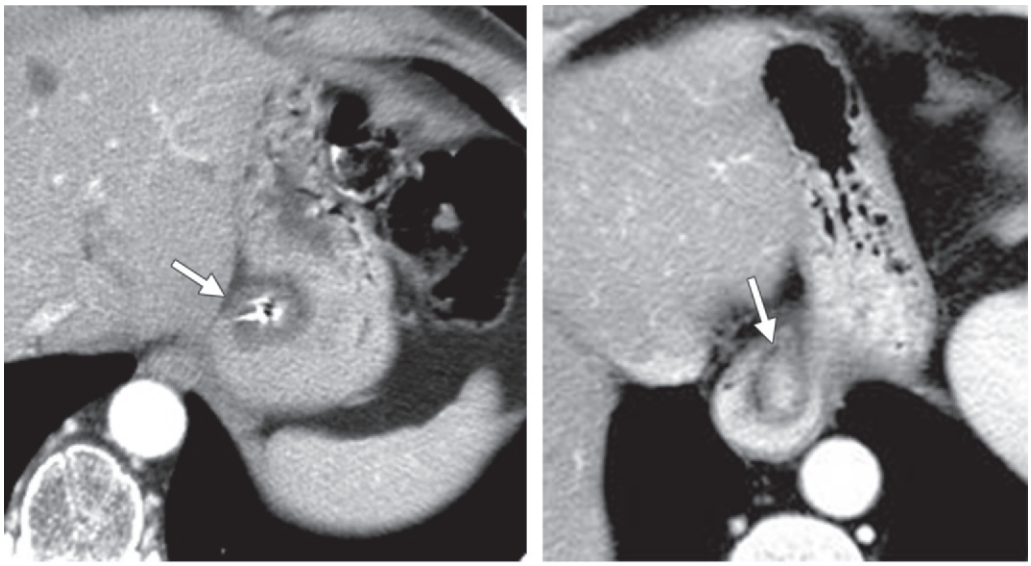
to facilitate esophageal clearance in patients with poor esophageal motility (1,5).

Postoperative Imaging Evaluation

An upper gastrointestinal series obtained with water-soluble contrast material should be performed immediately after surgery to rule out leakage, detect impaired esophageal emptying, and, if possible, assess the location of the wrap. Follow-up barium examination is indicated by most surgeons when there are persistent or new symptoms that are suspicious for surgical failure or recurrence of reflux-like dysphagia or heartburn (6–8).

Teaching Point

In a follow-up double-contrast upper gastrointestinal series, the fundoplication wrap is seen as a deformity of the gastric fundus with a mostly anterior, smooth, well-circumscribed filling defect. The distal esophagus is narrowed and gently curved as it passes through the wrap itself (Fig 4a, 4b). At single-contrast barium examination, the narrowed distal esophagus is seen passing through the central portion of the gastric fundal pseudomass, with mucosal



a. b.

Figure 5. CT appearance after fundoplication repair. Axial contrast-enhanced CT images show an infradiaphragmatic esophagus (arrow in **a**) surrounded by a gastric wrap filled with positive gastrointestinal contrast material; the gastric wrap has a whirled appearance (arrow in **b**).

Fundoplication Complications, Characteristic Clinical Findings, and Imaging Correlation

	Clinical Findings		Imaging Correlation			
Complication	Obstruction Symptoms	Reflux Symptoms	Intact Wrap	Supradiaphragmatic Wrap Migration	Slipped Stomach	Recurrent Hiatal Hernia
Tight Nissen	Yes	No	Yes	No	No	No
Patulous Nissen	No	Yes	Yes	No	No	No
Wrap disruption	No	Yes	No	NA	No	Yes
Supradiaphragmatic gastric slippage	Yes	Yes	Yes	No	Yes	Yes
Slipped Nissen	Yes	Yes	Yes	No	Yes	No
Transdiaphragmatic wrap migration	Yes	Yes	Yes	Yes	No	NA

Note.—NA = not applicable.

integrity. When the patient is in the supine position, the fundal wrap defect may form an acute angle at the fornix created by the plication and the nonsurgical gastric wall and resemble an inverted "3" (Fig 4c). Retroverted endoscopic images of the gastric fundus demonstrate a protruded wrap surrounding the cardia (Fig 4d). CT images show the gastric fundus wrapped around the distal subdiaphragmatic esophagus (Fig 5) (9–12).

Complications

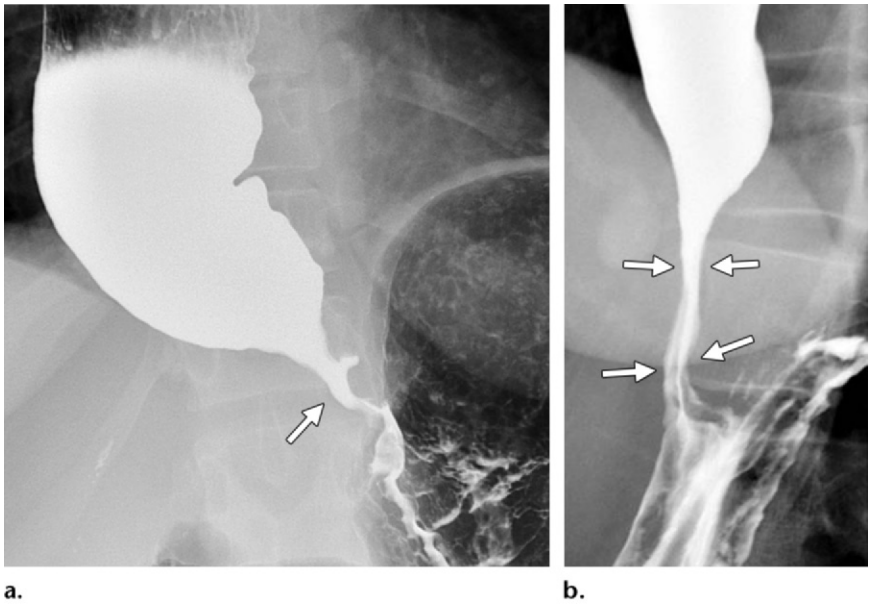
Laparoscopic Nissen fundoplication is an effective antireflux procedure with a long-term success rate of over 90% (2,8,13). Persistent or recurrent symptoms of reflux and/or persistent postoperative dysphagia are the most common indicators of fundoplication failure (13). Such failures are due to a fundoplication wrap that is too tight, too loose, disrupted, or incorrectly positioned or that has migrated into the chest (1,2,8,13–17). Correlation of symptoms and imaging findings is shown in the Table.

Teaching Point

Tight Nissen

A tight Nissen fundoplication refers to obstruction of the distal esophagus due to a fundoplication wrap that is too tight or too long (more than 2 cm) or a crural stenosis (8,13–15). Symptoms include dysphagia, bloating, and regurgitation of undigested food and persist several weeks after the procedure. Barium examination shows a smooth narrowing of the distal esophagus, with proximal luminal dilatation

Figure 6. Obstructive Nissen fundoplication. **(a, b)** Images from single-contrast barium studies in two different patients show distal esophageal luminal narrowing (arrows) due to too-tight **(a)** and too-long **(b)** fundoplications. **(c)** Axial contrast-enhanced CT image in the same patient as in **a** shows a luminal narrowing of the distal esophagus (arrow), with proximal dilatation.



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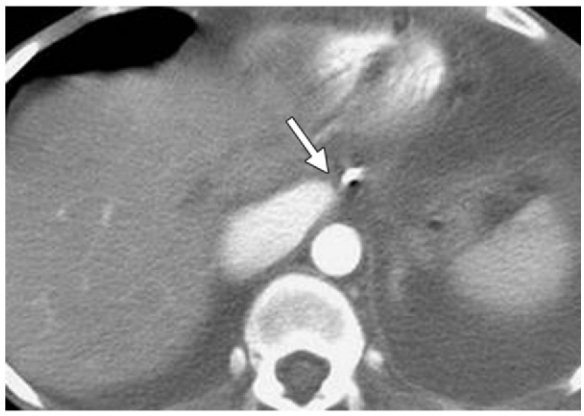


c.

and delayed esophageal clearance (15) (Fig 6). No gastroesophageal reflux or hiatal hernia is visualized at imaging. CT depicts a narrowing of the distal esophagus with proximal dilatation. A too-tight fundoplication can be treated by esophageal dilation; if unsuccessful, the fundoplication should be revised surgically, with either a "floppy" (loose) or partial fundoplication.

Patulous or Incompetent Repair

In a patulous or incompetent repair, the fundoplication wrap is complete and in place but too loose or patulous to adequately constrict the distal esophagus and construct an effective barrier to reflux. At barium examination, gastroesophageal reflux is visualized without recurrence of hiatal hernia. The gastric wrap is intact and infradiaphragmatic (16). Revisional surgery may be indicated if reflux and its complications cannot be controlled with medication.

Disruption of the Wrap (Hinder Type I)

Disruption of the fundoplication wrap (Hinder type I failure) involves partial or complete breakdown of the wrap and, in most cases, a recurrence of hiatal hernia (1,2,13,14) (Fig 7). The failure may be caused by disruption of the sutures due to the use of absorbable suture material, inadequate suture technique, or insufficient mobilization of the gastric fundus around the esophagus. At barium examination, the fundal defect is small or totally absent because of the failed wrap, and there is recurrence of hiatal hernia and reflux (18–21) (Fig 8). CT shows disruption of the wrap and recurrence of hiatal hernia (Fig 9). Revisional surgery may be indicated if medical treatment does not control the symptoms and complications of reflux.

Stomach Slippage above the Diaphragm (Hinder Type II)

In Hinder type II failure, the fundoplication wrap is maintained and remains infradiaphragmatic, but the proximal part of the stomach slips and reenters the chest (Fig 10a). The slipped and herniated stomach may be compressed by the diaphragmatic crura (Fig 10b), or a paraesophageal hernia may develop if there is disruption of the crural closure (1,8,13–15). The slippage may be due to omission or breakdown of the sutures that incorporate the esophageal wall to the wrap or incorrect placement of the wrap around the

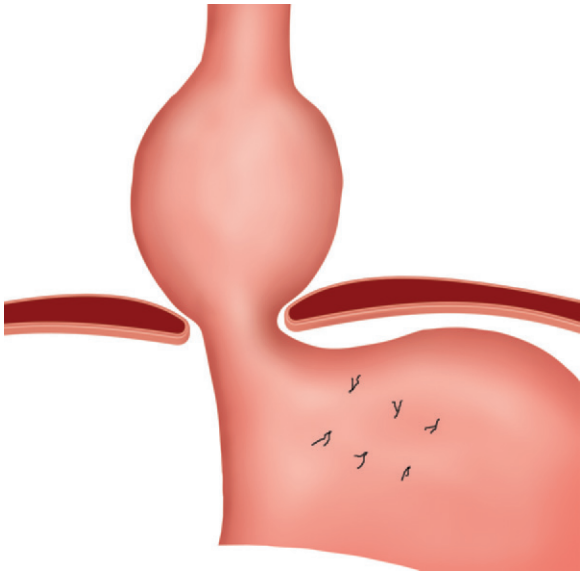
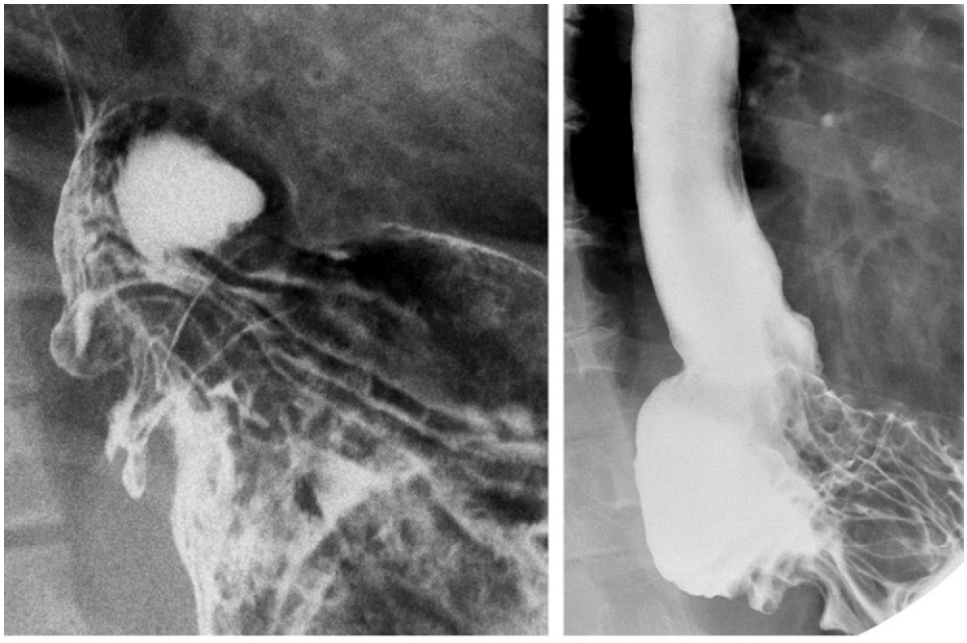


Figure 7. Drawing shows complete disruption of a fundoplication wrap, with recurrence of a hiatal hernia.



a. **b.**

Figure 8. Partial breakdown of a fundoplication wrap. Images from a double-contrast barium examination reveal partial wrap disruption, with recurrence of a hiatal hernia shown in **a** and reflux shown in **b**.

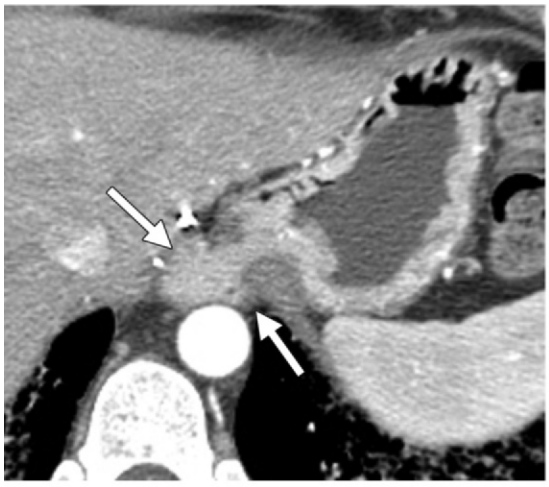
upper stomach rather than around the esophagus. There are symptoms of reflux and dysphagia if the slipped stomach is compressed by the diaphragmatic crura.

At barium examination and CT, the intact wrap is seen below the diaphragm, and the slipped stomach is herniated into the chest. Complete migration of the slipped stomach into the chest is seen as a hiatal or paraesophageal hernia (Fig 11a, 11b). If only part of the slipped stomach migrates into the chest and the other portion remains infradiaphragmatic, compression of the crura may create an hourglass deformity (13,15,18,19) (Fig 11c). Surgical revision is indicated if the symptoms of reflux cannot be medically controlled.

Slipped Nissen (Hinder Type III)

In Hinder type III failure, slippage of the proximal stomach through the unbroken wrap creates a pouch below the diaphragm without recurrence of hiatal hernia (1,2,13–15,18,19) (Fig 12). The failure may be caused by incorrect placement of the wrap around the stomach instead

a.



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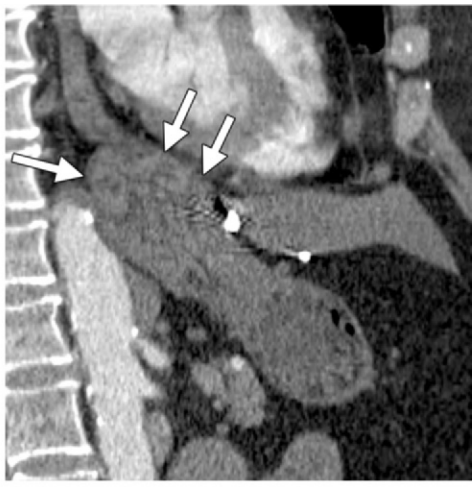


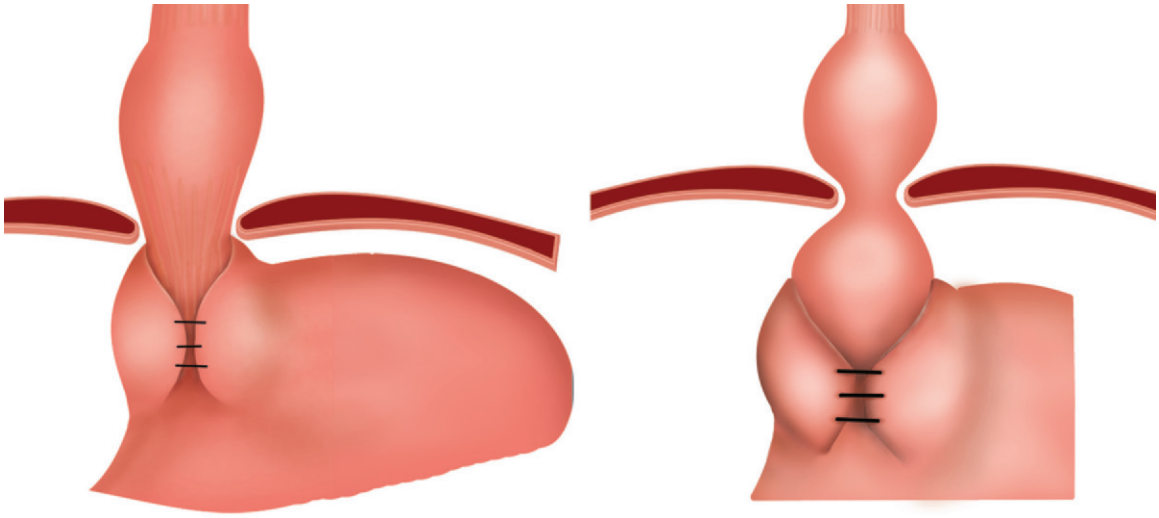
c.

Figure 9. Complete breakdown of fundoplication wrap in three different patients. Image from a double-contrast barium examination **(a)**, axial contrast-enhanced CT image **(b)**, and coronal oblique reconstructed CT image **(c)** show a recurrent hiatal hernia (arrows in **b** and **c**) without visualization of the gastric wrap.

of around the esophagus. Other causes are strain attributable to an undetected short esophagus or an inadequate mobilization of the gastric fundus. Midgastric obstruction or compression of the distal esophagus by the distended proximal gastric pouch may cause dysphagia and reflux of food after eating. At barium examination, the midstomach has a circumferential constriction due to the fundoplication wrap, with the slipped gastric fundus forming a proximal infradiaphragmatic pouch without recurrence of hiatal hernia. When the gastric lumen is distended, an hourglass deformity is seen (13,14,18–21) (Fig 13). Symptomatic midgastric obstruction requires surgical repair.

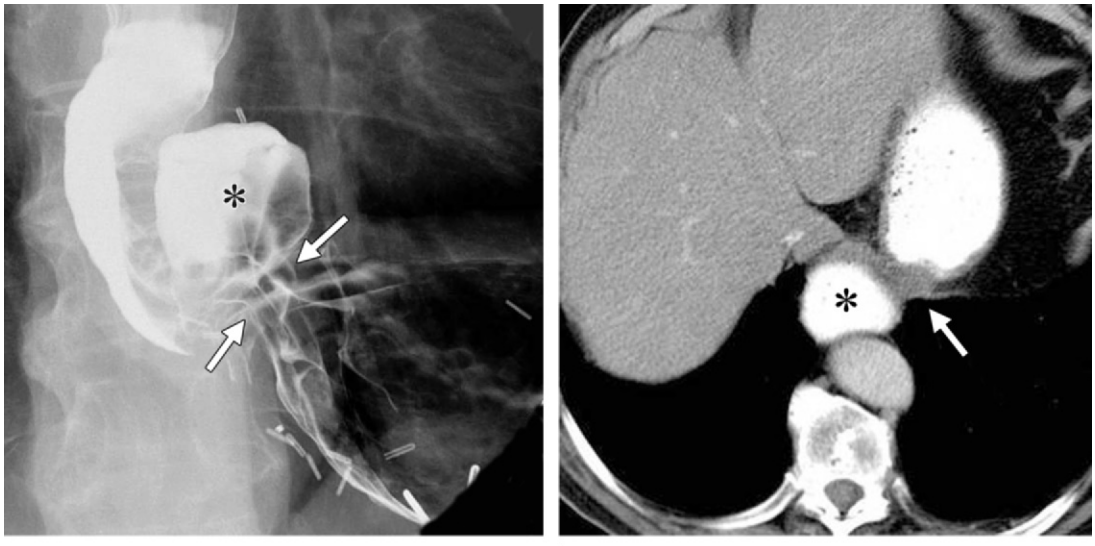
Transdiaphragmatic Wrap Herniation (Hinder Type IV)

In transdiaphragmatic wrap herniation (Hinder type IV failure), the intact gastric wrap migrates to the chest through the hiatus of the diaphragm (1,2,8,14,18,19) (Fig 14). The failure may be due to inadequate mobilization of a short esophagus or inappropriate repair of the diaphragmatic hiatus. Patients may have recurrent symptoms of reflux or obstruction due to compression of the stomach by the diaphragmatic hiatus. At barium examination and CT, the intact wrap and distal esophagus are visualized above the diaphragm (14,18,19,21). Stomach compression by the diaphragmatic hiatus produces an hour-



a. b.

Figure 10. Supradiaphragmatic migration of a slipped stomach. **(a)** Drawing shows slippage of part of the stomach through a maintained fundoplication wrap, with recurrence of a hiatal hernia. **(b)** Drawing shows an hourglass deformity of the slipped stomach, which is constricted by the diaphragmatic crura.



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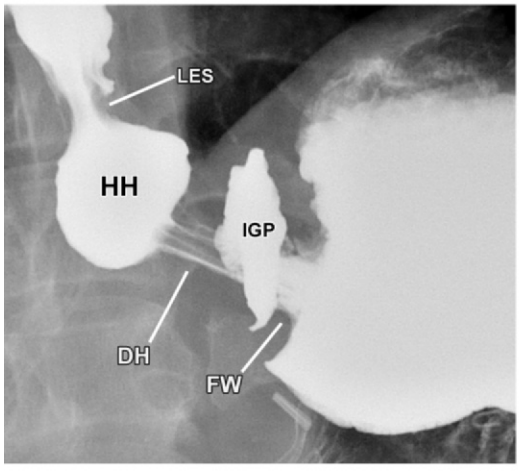


c.

Figure 11. Supradiaphragmatic migration of a slipped stomach. **(a, b)** Image from a double-contrast barium study **(a)** and axial contrast-enhanced CT image **(b)** show an infradiaphragmatic gastric stricture (arrows) due to the fundoplication wrap, with hernia recurrence (*). **(c)** Image from a barium examination shows an hourglass deformity of the slipped stomach, with an infradiaphragmatic pouch *(IGP)* separated from the hiatal hernia *(HH)* by the diaphragmatic hiatus *(DH)*. *FW* = fundoplication wrap.

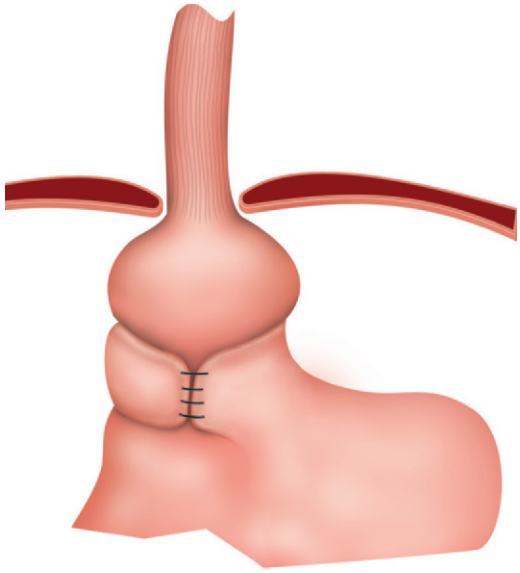
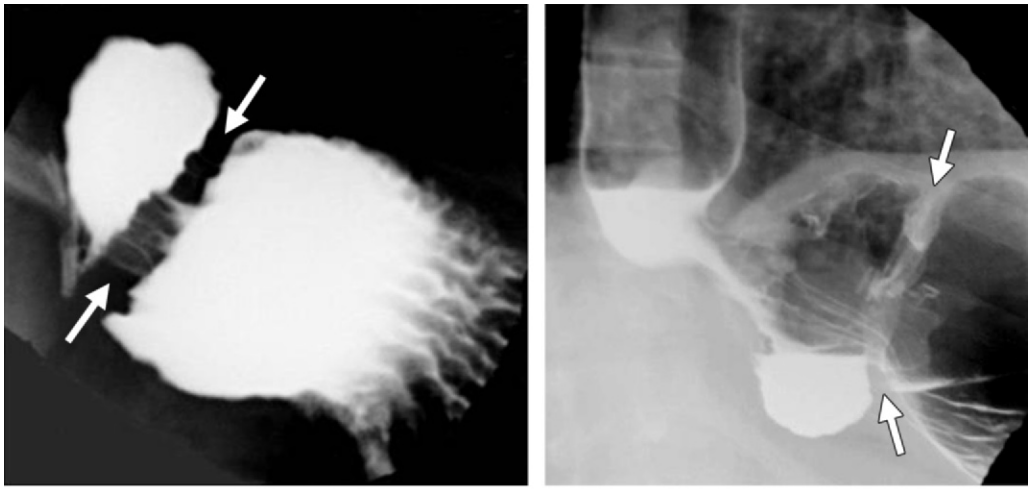


Figure 12. Drawing shows stomach slippage through an intact fundoplication wrap, with a proximal gastric pouch formed below the diaphragm.



a. **b.**

Figure 13. Slipped Nissen fundoplication. Images from single-contrast **(a)** and double-contrast **(b)** barium studies show a stricture of the midgastric lumen caused by a slipped wrap (arrows), with a proximal gastric pouch seen below the diaphragm.

glass deformity seen at barium examination (Fig 15). If symptoms are not controlled medically, surgery may be required to reposition the wrap into the abdomen.

Redo Fundoplication

The long-term postoperative outcome for fundoplication is excellent. Nissen surgical repair has proven to be durable over many years of follow-up; however, 2.8% of patients who undergo fundoplication require revisional (redo) fundoplication within 2 years of the initial operation. Redo fundoplications are technically challenging, with a lower success rate than the initial operation (79%–86%) and the potential for increased morbidity and mortality (2,8,22). Indications for a second operation include inefficient esophageal emptying due to a too-tight wrap that does not respond to dilation or a misdiagnosed esophageal motility disorder. Patients with uncontrolled recurrent reflux due to a patulous, disrupted, slipped, or migrated wrap may benefit from revisional surgery. In addition, a recurrent paraesophageal hernia or obstructed stomach caused by a slipped or migrated wrap may require reoperation (2,8,22).

Conclusion

Radiologic imaging is useful in evaluating postsurgical anatomy, detecting and characterizing the anatomic and physiologic abnormalities responsible for fundoplication failure, and assisting the surgeon in planning a revisional operation when indicated.

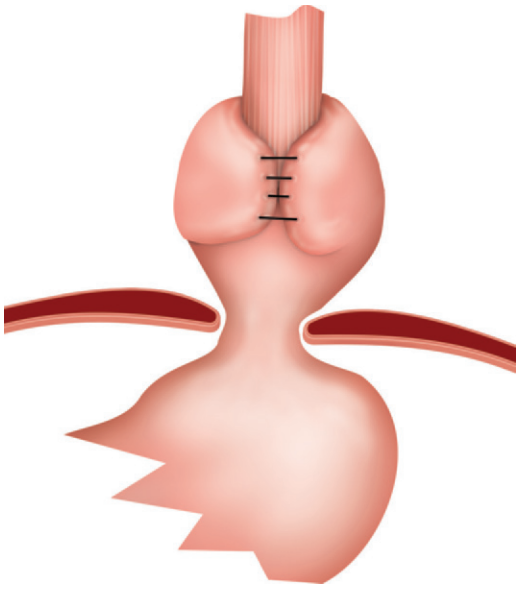
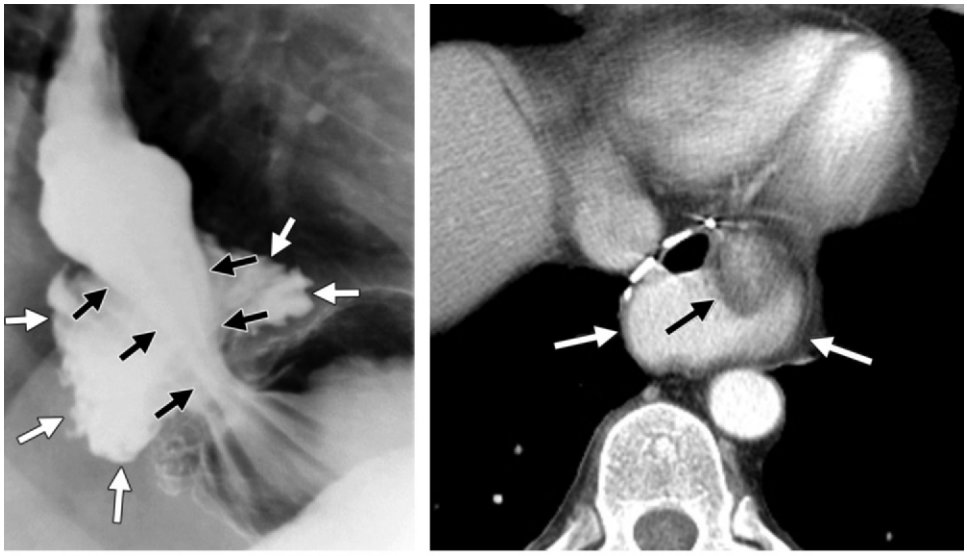


Figure 14. Drawing shows herniation of an intact fundoplication wrap into the chest through the hiatus of the diaphragm.



a. **b.**

Figure 15. Transdiaphragmatic wrap herniation. Image from a barium study **(a)** and axial contrast-enhanced CT image **(b)** show an intact fundoplication wrap located in the chest (white arrows) and surrounding the distal esophagus (black arrows).

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Imaging Findings of Successful and Failed Fundoplication

Alberto I. Carbo, MD • Roger H. Kim, MD • Thomas Gates, MD • Horacio R. D'Agostino, MD

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In cases of failed fundoplication, barium examination of the upper gastrointestinal tract and CT assist in evaluating the postsurgical results. Imaging provides information to help the physician understand the mechanism of failure and its functional consequences, determine whether further surgery is necessary, and select the appropriate surgical procedure.

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Preoperative evaluation of patients with GERD includes videoesophagography or an upper gastrointestinal series. The radiologic examination includes double-contrast gastrointestinal radiography. The barium examination is performed to diagnose a hiatal hernia that may need to be reduced or a shortened esophagus that may necessitate a lengthening procedure. In addition, the study may help visualize reflux and detect complications such as esophageal ulcerations and strictures. The imaging examination should include an evaluation of the swallowing mechanism to diagnose abnormalities associated with chronic reflux, such as cricopharyngeal dysfunction, and assessment of esophageal function to identify esophageal motility disorders that may require a different surgical technique.

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Surgical antireflux techniques are used to correct anatomic and functional abnormalities that cause reflux. These rectifications include reduction of a hiatal hernia by returning the LES to the abdomen and re-creation of the esophagogastric angle to act as a nonrefluxing valve. Construction of a gastric wrap around the distal esophagus supports the LES in place and increases its resting pressure. Finally, approximation of the diaphragmatic crura helps hold the fundoplication wrap in the abdomen and assists the sphincter in creating an adequate pressure.

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In a follow-up double-contrast upper gastrointestinal series, the fundoplication wrap is seen as a deformity of the gastric fundus with a mostly anterior, smooth, well-circumscribed filling defect. The distal esophagus is narrowed and gently curved as it passes through the wrap itself.

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Persistent or recurrent symptoms of reflux and/or persistent postoperative dysphagia are the most common indicators of fundoplication failure. Such failures are due to a fundoplication wrap that is too tight, too loose, disrupted, or incorrectly positioned or that has migrated into the chest.