Gastroesophageal Reflux Disease: Integrating the Barium Esophagram before and after Antireflux Surgery[1]

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Gastroesophageal reflux disease (GERD) is a common medical problem in the United States. As a result, laparoscopic antireflux surgery is a common surgical procedure. At the authors' institution, the barium esophagram before and after antireflux surgery is a critical examination in patients with GERD. This article summarizes the authors' examination protocol and describes how the findings are integrated in the care of these patients.

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Gastroesophageal reflux disease (GERD) is a substantial health problem in the United States affecting large numbers of individuals and consuming health care dollars (1–3). While the majority of patients with GERD are treated medically and require neither a barium examination nor endoscopy (4), there is no consensus as to what tests should be performed in evaluating patients with GERD either before or after antireflux surgery. At many institutions, because of lack of training or disinterest on the part of radiologists, and because of the bias of gastroenterologists and surgeons, endoscopy has almost completely replaced the barium examination in the evaluation of the esophagus.

For the past 10 years at the Cleveland Clinic Foundation, there has been a multidisciplinary center for swallowing and esophageal disorders, where more than 2400 patients with GERD are evaluated per year. Virtually all of these patients undergo barium esophagography as part of their evaluation prior to surgery. Since the inception of the center, physicians from the departments of gastroenterology, otolaryngology and speech disorders, radiology, and thoracic surgery have met biweekly to review and discuss the clinical, radiographic, manometric, and endoscopic findings in patients with esophageal diseases. In those discussions, the barium esophagram is often critical in the evaluation of the patient. As a result of these case discussions, we have over time developed a focused approach to the role of the esophagram in the evaluation of patients with GERD both before and after antireflux surgery.

With the advent of laparoscopic fundoplication in the United States, we are evaluating more patients before and after antireflux surgery. Because our approach is multidisciplinary and is applied to a large number of patients, we thought it timely to communicate our esophagography technique, the important factors we evaluate, and how the findings are integrated into the care of patients with GERD both before and after antireflux surgery.

Essentials

- The barium esophagram provides essential information in the pre- and postoperative assessment of patients with gastroesophageal reflux disease (GERD).
- Preoperatively, the most important finding in a patient with GERD is a foreshortened esophagus; the most common findings of a foreshortened esophagus are a large (> 5-cm) hiatal hernia, a hiatal hernia that does not reduce when the patient is in the upright position, and a stricture.
- Postoperatively, the cause of symptoms can often be best identified with the esophagram.
- A common finding in a patient with recurrent reflux is a disrupted and/or herniated fundoplication.
- A common finding in a patient with postoperative dysphagia is a tight, long fundoplication surrounding the stomach.

Barium Esophagram

The barium examination of the esophagus requires a tailored and flexible approach by the radiologist. We start with a short history to determine the presence and frequency of symptoms, including solid and liquid dysphagia, chest pain, regurgitation, and heartburn, and we tailor our examinations accordingly. Our examination of the esophagus can be separated into seven phases (5,6): *(a)* the timed barium swallow (7); *(b)* the upright, mucosal or air-contrast phase; *(c)* the motility phase; *(d)* the distended or single-contrast phase; *(e)* reflux identification; *(f)* the solid food phase; and *(g)* the oropharyngeal phase. In our practice, the oropharyngeal phase of the examination is not routinely used in patients with GERD.

Timed Barium Swallow Phase: Technique and Findings prior to Antireflux Surgery

Some patients with GERD symptoms do not have reflux disease but rather a misdiagnosed motility disorder. The classic symptoms of achalasia, which include chest pain, regurgitation, both solid and especially liquid dysphagia, and heartburn, may overlap with those of GERD. Therefore, any patient with liquid dysphagia is always evaluated first with a timed barium swallow study to assess esophageal emptying as a manifestation of impaired motility and lower esophageal sphincter relaxation (Fig 1) (7). This simple technique rapidly and accurately quantifies esophageal emptying, an early and essential step in detecting and assessing achalasia or another severe esophageal motility disorder such as a diffuse esophageal spasm (Fig 2) (8,9). If the timed barium swallow phase shows no substantial emptying problems, we then continue with the standard study, starting with the upright air-contrast portion of the examination. If emptying is impaired, we often move to an assessment of motility. Anecdotally, if a timed barium swallow study is performed prior to the upright air-contrast phase of the examination, then the mucosal coating does not seem to be substantially altered.

Upright Air-Contrast Phase: Technique and Findings prior to Antireflux Surgery

Since all of our preoperative patients with GERD have undergone or will undergo endoscopy, we believe that the most important aspect of the upright double-contrast or mucosal phase of the barium examination is not the detection of mucosal abnormalities but the detection of a foreshortened esophagus. This reflects an institutional bias but is also the standard in other medical centers (4). However, the air-contrast portion of the examination may be the only assessment of the mucosa in patients. In other institutions, the barium examination is used as an alterna-

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Abbreviation:
GERD = gastroesophageal reflux disease

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tive means to detect esophagitis and other findings associated with GERD, which are often present in patients with Barrett esophagus (10,11).

Many patients with classic GERD have some form of hernia, especially those with esophagitis (12). The anatomy of hiatal hernias was defined in the 1950s and 1960s (13–15). Four types were defined: type I, or axial, sliding hiatal hernia; type II, or true paraesophageal hernia without displacement of the gastroesophageal junction; type III, or paraesophageal hernia (sometimes called mixed hernia) with intrathoracic displacement of the gastroesophageal junction; and type IV, which is a type III hernia that also includes additional intraabdominal organs, such as the colon, displaced into the chest. In the evaluation of GERD, the radiographic identification of the hiatal hernia type is less important unless there is a type II or III paraesophageal hernia, which may become incarcerated. The critical finding is whether the hernia is present in the upright position (16–18) (Fig 3). If the hernia is identified in the upright position, we assume that there is esophageal foreshortening. In addition, the esophagus is probably shortened when there is a hiatal hernia 5 cm or greater alone or in combination with a stricture or a long-segment (≥3-cm) Barrett esophagus (19–21) (Fig 4). Other findings that suggest a foreshortened esophagus include severe extensive ulcerative esophagitis, straightening or loss of the angle of His, the presence of a stricture alone, and type III mixed or complex paraesophageal hernias (17,22–24).

It is important to identify a scarred foreshortened esophagus, because many surgeons believe that a lengthening procedure, such as a Collis gastroplasty or a more extensive esophageal mobilization, is essential for an adequate antireflux operation in these patients (16,17, 19,25,26). Today, most antireflux operations are performed laparoscopically. The pneumoperitoneum necessary to perform laparoscopy elevates the diaphragm superiorly into the mediastinum and spuriously "lengthens" the esophagus. If a laparoscopic procedure is performed without recognition that

Figure 1

Patient stands and remains upright throughout the entire study.

Patient ingests 100–250 mL of low-density barium (45% wt/vol) over 35–40 seconds, with barium volume ingested based on patient tolerance.

Three-on-one spot radiographs (14 × 14 or 14 × 17 inches) are obtained 1, 2, and 5 minutes after ingestion, with the patient in left posterior oblique postion. The distance of the fluoroscopic carriage from the patient is kept constant for all spot radiographs. The 2-minute radiograph is optional, but fluoroscopic image at 2 minutes is used to determine the state of emptying. If esophageal diameter is greater than 7–9 cm, the radiologist must often use a two-on-one format to include the entire esophagus.

The degree of emptying is estimated qualitatively by comparing the 1- and 5-minute radiographs. It may also be estimated by measuring the height and width for both radiographs, calculating the rough area for both, and determining the percentage of change in the area.

Figure 1: Instructions for timed barium swallow technique.

Figure 2

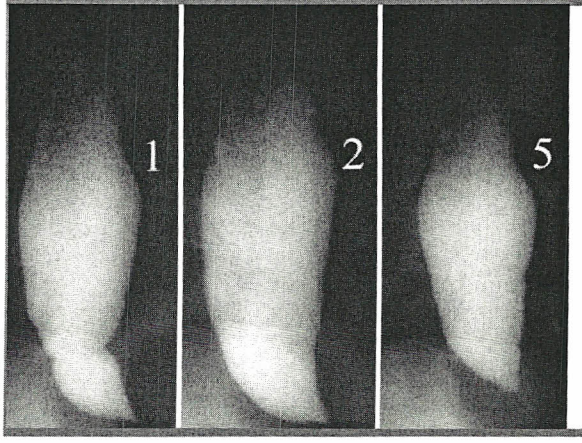


Figure 2: Timed barium swallow phase of esophagography after ingestion of 250 mL of low-density barium in a patient with achalasia. Anteroposterior three-on-one spot radiographs in upright position (*1*, *2*, and *5* = 1, 2, and 5 minutes, respectively) after barium ingestion show poor esophageal emptying.

Figure 3

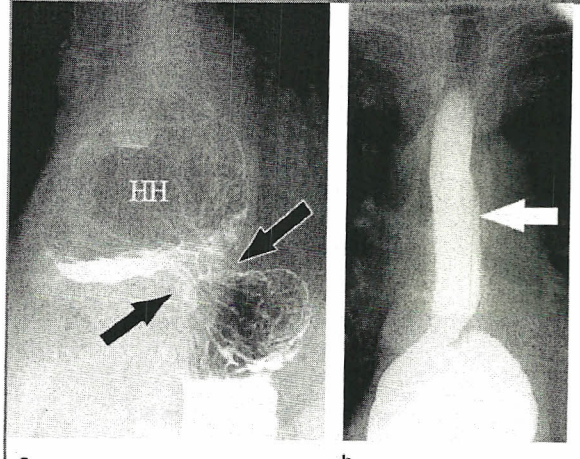


Figure 3: Large nonreducible hiatal hernia with high-volume reflux in a patient with heartburn and dysphagia. **(a)** Upright anteroposterior air-contrast esophagram shows large (> 5 cm in size) nonreducible hiatal hernia *(HH)*; findings indicate a foreshortened esophagus. The arrows point to the diaphragm. **(b)** Supine anteroposterior esophagram during reflux identification portion of esophagography shows spontaneous, high-volume reflux (arrow), which did not clear rapidly. Motility portion of the examination showed aperistalsis.

the esophagus is shortened, there may be an unrecognized inadequate length of intraabdominal esophagus at surgery. Further, the surgeon may not be able to accurately assess whether the esophagus has been adequately mobilized for hernia reduction without tension. With the repair constructed under tension on a short esophagus, the hernia is reduced below the diaphragm at surgery and then retracts into the chest over time. The fundoplication may or may not remain subdiaphragmatic or it may disrupt or "slip" onto the stomach. It is our opinion that most slipped Nissen fundoplications result from the failure to recognize a foreshortened esophagus before surgery.

Motility Phase: Technique and Findings prior to Antireflux Surgery

The motility phase is performed with the patient in "gastrointestinal" or semiprone right anterior oblique position. It is important that patients are in a true horizontal position to eliminate the effect of gravity. We use low-density barium (45% wt/wt, 68% wt/vol) and ask the patient to ingest a single small (5–10-mL) mouthful of barium.

Fluoroscopy should start in the oropharynx and focus on the proximal end of the barium column, which takes the shape of an inverted *V*. Compared with simultaneous manometry, this inverted *V* corresponds to the start of the upstroke of the primary peristaltic wave (27,28). The inverted *V* of the barium column should rapidly and consistently progress distally to the level of the gastroesophageal junction (a progressive aboral wave). Each swallow should be separated by at least 25–30 seconds. Generally, our patients perform five separate swallows, unless there is consistent abnormal pattern after three swallows (28). This phase should be recorded on videotape so that the findings may be reviewed.

Several aspects of the motility portion of the examination bear emphasis. There is a normal transient slowing of the inverted *V* at the juncture of the proximal and middle one-third of the esophagus at the transition from skeletal to smooth muscle, which is generally located at the level of the aortic arch. Any barium that escapes proximally from the inverted *V* should be initially ignored as the barium column is followed fluoroscopically (ie, a very small volume of escaped barium is normal). After the inverted *V* has reached the gastroesophageal junction, the more proximal esophagus is examined fluoroscopically to identify secondary stripping of the escaped barium. In many patients with dysphagia and reflux, it is common that the primary peristaltic wave does not propagate or that it propagates inconsistently. Sometimes, secondary peristaltic waves propel the barium distally. Assessment of the robustness or amplitude of the primary peristaltic wave is subjective. We use the following subjective terms: normal peristalsis; low amplitude, nonocclusive peristalsis (ie, substantial retrograde escape); nonsegmental tertiary contractions (nonocclusive contractions); segmental tertiary contractions (occlusive contractions); and aperistalsis.

The fluoroscopic assessment of esophageal motility is very helpful in evaluating a patient with GERD. Dysmotility in GERD patients is well known (29–32). One recent report estimates that up to 35% of patients with nonspecific esophageal dysmotility have GERD (32). In our experience, most patients presenting with dysphagia have direct or indirect evidence of reflux disease (reflux identified fluoroscopically or presence of persistent cricopharyngeal bar, hiatal hernia, or a subtle distal mucosal ring). Most of these patients have at least mild dysmotility. More often, the esophagus demonstrates low-amplitude nonocclusive peristalsis with substantial retrograde escape. In some patients, there are vigorous nonpropulsive tertiary contractions. In both groups, a normal lower esophageal sphincter excludes achalasia.

Figure 4

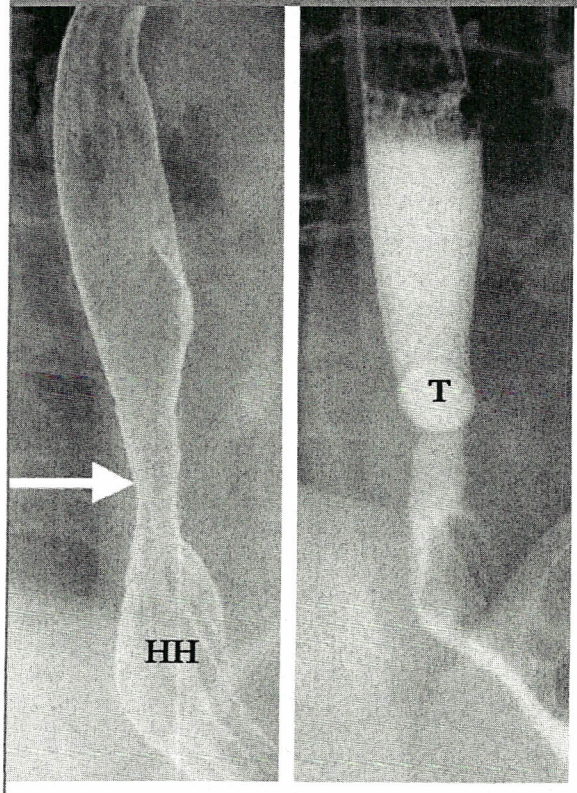


Figure 4: Long distal peptic esophageal stricture strongly suggesting foreshortened esophagus. **(a)** Upright anteroposterior air-contrast esophagram shows stricture (arrow) and nonreducible hernia *(HH)*. **(b)** Upright anteroposterior esophagram after ingestion of 13-mm tablet *(T)* and barium shows obstruction of tablet at the stricture.

In our experience, the motility portion of the barium examination is used to complement the standard manometric study. However, in cases where a surgeon does not perform preoperative manometry, the motility portion of the barium examination is the only assessment of motility. In these cases, it is essential to identify a patient with a severe motility disorder such as achalasia for proper treatment. We have seen several patients with unrecognized achalasia treated with a fundoplication. In addition, manometry measures luminal pressure change, while the motility portion of the esophagram measures bolus transit. This essential difference in the tests has been elucidated by comparisons of manometry and impedance monitoring (a new technique that assesses bolus transfer in the esophagus) (33). In evaluating patients with ineffective esophageal motility (defined by contractions of <30 mm Hg) with simultaneous manometry and impedance, Tutian and Castell (33) found that 48% of liquid swallows and 34% of viscous swallows had complete bolus transfer. According to manometric criteria, these were considered abnormal. This discrepancy between bolus transit and manometry has been confirmed by others (34). In our experience of concurrent video esophagrams and impedance monitoring, barium studies mimic impedance findings (35,36). Even if impedance is available, the motility portion of the barium examination adds little time to the evaluation and can provide helpful information. In general, patients with poor or absent peristalsis often do not do well after a complete 360° Nissen fundoplication, because the low-amplitude pressure wave of the esophagus is inadequate to overcome the pressure gradient created by the Nissen fundoplication. In these patients, some surgeons would consider a partial wrap, such as a 270° Toupet fundoplication, in an attempt to avoid dysphagia that might occur after a complete 360° fundoplication. We perform Nissen fundoplications for all but aperistaltic esophagi. Amplitude is a factor, but the number of nonconducted waves is equally important.

Distended Single-Contrast Phase: Technique and Findings prior to Antireflux Surgery

The distended single-contrast phase is performed with the patient in the right anterior oblique position and is also videotaped before spot radiographs are obtained. Many radiologists position the patient over a bolster during this phase to increase intraabdominal pressure, although we do not do so. This is said to help identify small sliding hiatal hernias. This phase is critical in identifying subtle distal strictures that can be missed by even skilled endoscopists. It is important to recognize that patients with chronic strictures have unconsciously accommodated to this problem and often find it difficult to rapidly ingest barium in this position. The radiologist must strongly encourage these patients to rapidly drink in order to identify these strictures (Fig 4). During this phase, we generally perform fluoroscopy for 3–6 seconds while panning down the esophagus, concentrating on the distal esophagus and gastroesophageal junction. We identify more subtle strictures, contour abnormalities, and distal mucosal rings on the videotape than on spot radiographs. Spot radiographs are obtained after we have thoroughly examined the esophagus fluoroscopically. During this phase, we also identify most small type I hernias due to the increased intraabdominal pressure caused by the semiprone position of the patient.

Reflux Identification: Technique and Findings prior to Antireflux Surgery

We use provocative maneuvers during the gastroesophageal reflux assessment phase. These include leg raise, cough, Valsalva maneuver, and water siphon test. After the full-column or distended phase, while the patient is lying in semiprone position, we fluoroscopically examine the entire esophagus to confirm that all of the ingested barium has cleared the esophagus. If it has not cleared after several seconds, we raise the patient to a 45° semierect position and fluoroscopically confirm that the barium has cleared the esophagus. If barium remains in the esophagus despite positional change, we have the patient ingest several swallows of water. We then bring the patient to the horizontal position and ask him or her to assume the supine position. At this point, any fluoroscopically identified esophageal barium must have resulted from reflux. If none is present, we then proceed with a fluoroscopic assessment after a leg raise, cough, Valsalva maneuver, and water siphon test. For a Valsalva maneuver, we take a lead-gloved hand, press on the patient's abdomen, and ask him or her to push against the hand, contracting their abdominal muscles. Using this technique, the radiologist can feel whether the anterior abdominal muscles are contracting. The water siphon test is performed with the patient in a slight right posterior oblique position, while ingesting several swallows of water. During that time, the distal esophagus is assessed fluoroscopically. Whenever reflux is identified, the maneuver causing the reflux and the height and reflux clearance time are recorded. Clearance time is subjectively divided into less than 30 seconds and more than 30 seconds.

The effectiveness and importance of reflux identification during barium studies have been questioned by many authors (37). Many studies have shown that the barium examination is insensitive when compared with 24-hour pH studies (37). However, Thompson et al (38) studied 117 patients with clinical findings suggestive of reflux by using barium esophagrams and 24-hour pH studies (70 had positive and 47 had negative 24-hour pH study findings). They found that with increasing number of provocative maneuvers, starting with a cough and then proceeding to a Valsalva maneuver, rolling the patient, and water siphon test, a 70% sensitivity and a 74% specificity could be achieved vis-à-vis 24-hour pH studies. Our experience confirms the findings of Thompson et al. In a relatively small number of patients (n = 26), barium had a 65% sensitivity and a 67% specificity relative to 24-hour pH studies (the Cleveland Clinic Foundation, unpublished data, 2000).

In our practice, the sensitivity of barium examination in reflux identification is largely irrelevant. As with the motility findings of a barium study vis-à-vis manometry, the barium assessment of reflux provides the gastroenterologist and surgeon with information complementary to that of 24-hour pH studies. In our practice, the most important part of reflux identification is the volume of the reflux (ie, height of barium reflux) and the rate of refluxed barium clearance from the esophagus. There is no other method available to measure reflux volume. We believe that identifying a large-volume (into the proximal esophagus) poorly clearing reflux episode or continuous spontaneous reflux at barium examinations is more important than just a single, small, rapidly clearing episode (Fig 3). We do not believe that trace low-volume reflux, which rapidly clears, is clinically important.

Solid Food Phase: Technique and Findings prior to Antireflux Surgery

The last portion of the examination involves ingesting some solid material or food. At our institution, we initially use a 13-mm barium sulfate tablet (E-Z-Em, Westbury, NY). Others use marshmallows cut into various well-defined sizes (39). In the upright position, the patient swallows the tablet with water. In some patients, this tablet transiently slows or stops at the level of the aortic arch. This will clear rapidly with another swallow of water and is normal. The tablet may also get caught in the valleculae, which may or may not be due to an oropharyngeal problem. The tablet is most useful in detecting or confirming a subtle distal esophageal stricture or the importance of a distal mucosal ring already identified at previous portions of the examination (Fig 4). Many patients with a subtle stricture have accommodated to that stricture by taking progressively smaller boluses of food or liquid. Despite encouraging efforts, they simply will not rapidly ingest an adequate volume of barium during the single-contrast phase of the examination to demonstrate the stricture. A pill will confirm the presence of such a stricture. If it is obvious that a ring or stricture will obstruct the tablet, we generally do not use the tablet, although most of our referring physicians prefer that we use the tablet.

We have also given patients barium paste with pudding or graham cracker and assessed the degree of emptying of these substances. Because there are no standards for solid food passage, we have found interpretation to be very difficult and have largely abandoned this part of the examination. However, there are cases where solid food is helpful in confirming specific complaints. Some patients thought to have GERD may complain of dysphagia only with certain foods, such as chicken or bread. In our practice, when a patient has dysphagia involving a specific food, the referring gastroenterologist or surgeon encourages that patient to bring the particular food with him or her to the examination so that solid food emptying can be observed. As with pudding, we add barium paste to the food and have the patient chew the mixture and then swallow. Sometimes with these patients, symptoms are encountered without any structural or motility abnormality. We find that when the patient views the video and is assured that no abnormality exists, his or her symptoms often improve. In this way, inappropriate antireflux surgery may be prevented.

At the end of the examination, our radiology report specifically addresses findings that are pertinent to the gastroenterologist and surgeon. These are summarized in Figure 5.

Figure 5

Emptying assessment in patients with liquid dysphagia (timed barium swallow).

Presence and type of hernia.

Reducibility of hernia in the upright position.

Esophageal motility.

Reflux identification, including maneuvers that elicit reflux, the height of reflux, and the time to clear the refluxed material.

Presence of a stricture or distal mucosal ring.

Figure 5: Issues that should be addressed in an esophagram report in a patient suspected of having GERD.

Patient Presentation after Antireflux Surgery

Broadly, there are five symptom complexes that patients present with after antireflux surgery that may indicate a complication (40–44). Prior to the examination, it is helpful to know the patient's predominant symptom and whether the symptoms improved or are different after the antireflux surgery. These symptoms are dysphagia, epigastric pain and/or gas bloat, nausea and/or early satiety, recurrent reflux, and symptoms that have not changed after antireflux surgery. In general, those patients who have had no symptomatic relief immediately after antireflux surgery probably did not have GERD as the cause of their symptoms. In most instances, these are patients with atypical symptoms that did not respond to medical treatment before surgery.

We find that a careful barium study gives the best assessment of anatomic problems contributing to these postfundoplication symptoms (45–49). The esophagram is considered the key test because it provides information concerning the postsurgical anatomy, the integrity of the fundoplication, the state of motility, and the presence of reflux, otherwise obtainable only by a battery of tests. In our experience, endoscopy tends to confirm the radiographic findings but generally adds little additional information. Esophageal manometry and 24-hour pH studies may help to better quantify the problems. As a result, all patients with postfundoplication symptoms have an esophagram as an essential and usually initial part of their evaluation.

Barium Esophagram: Technique and Findings Helpful after Antireflux Surgery

The examination after antireflux surgery is basically the same as for patients prior to surgery. However, there are some modifications and a different emphasis. As with patients prior to antireflux surgery, we find that a very easy way to initially assess emptying abnormalities in a patient with liquid dyspha-

gia after antireflux surgery is to perform a timed barium swallow. A tight fundoplication can often cause symptoms that mimic achalasia. Therefore, any patient with liquid dysphagia after antireflux surgery undergoes a timed barium swallow prior to the air-contrast portion of the examination. A normal esophagus should empty 250 mL of low-density barium within 1 minute. Any delay in emptying suggests that the fundoplication is too tight or that the peristalsis is inadequate (Fig 6).

If there is substantial retention of barium after the emptying study, we discuss the case and further assessment with the referring clinician and may only give a tablet to confirm the tightness of the fundoplication. If esophageal emptying is normal, we proceed with the upright air-contrast portion of the examination. In this phase, we make concerted effort to distend and coat the fundoplication. We achieve this by laying the patient in the supine position, allowing the high-density barium to reflux into the fundoplication. We then have the patient roll toward the left, then prone, then left, and then supine, several times, attempting to keep the barium in the stomach, as well as coat the fundus and fundoplication. We then place the patient in the right lateral decubitus position and elevate him or her 45°. At this point, a spot radiograph of the gastroesophageal junction is obtained. In most cases, the fundoplication is coated with barium and distended with gas. If it is not, we repeat the process. We then elevate the patient to the erect position and obtain spot radiographs in the anteroposterior and right and left posterior oblique positions. Using this technique, we identify the fundoplication, its length, its position vis-à-vis the diaphragm, and what it surrounds (stomach or esophagus). It is important for the radiologist to make every effort to not only distend but also to coat the fundoplication to determine its integrity. Because the lumen of the fundoplication is continuous with the stomach, one can often coat the mucosa and thus identify its location and boundaries.

After the mucosal phase of the examination, it is important to carefully perform a motility examination in the semiprone position. This is followed by the drinking or distended phase of the examination. During this phase, we focus on the distal esophagus and wrap location, fluoroscopically assessing the degree of distal esophageal distension to gauge the relative degree of obstruction caused by fundoplication. If we have not fully coated and distended the fundoplication during the mucosal portion of the examination, we often find that it is so during this portion of the examination. We also examine the fundoplication location, attempting to assess the length of the fundoplication and which lumen has been encircled by the fundoplication, either the stomach, the distal esophagus, or both. It is then important to have the patient swallow a 13-mm tablet and observe its course, especially

Figure 6

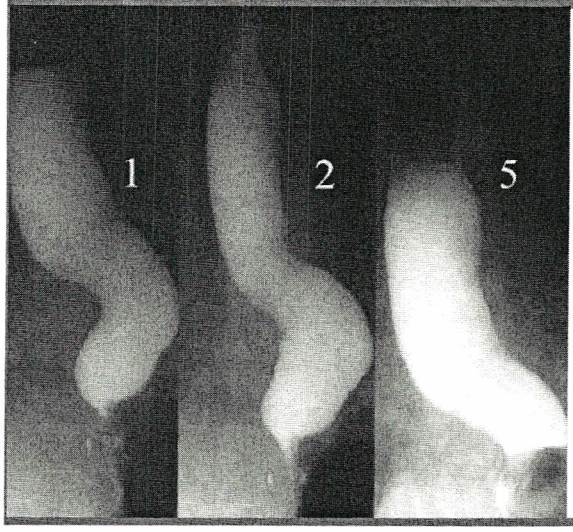
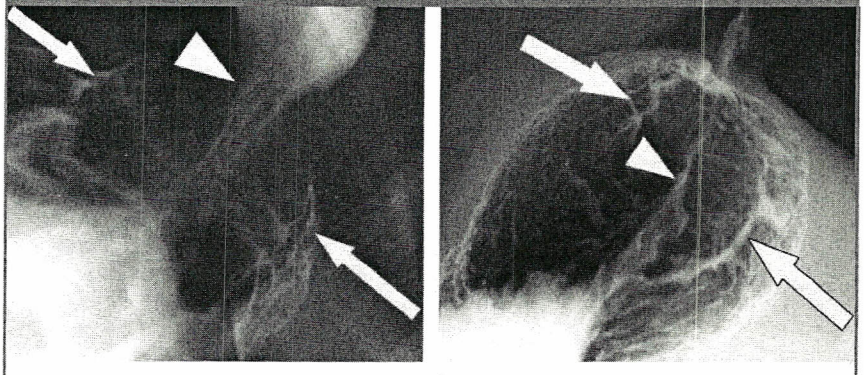


Figure 6: Timed barium swallow phase of esophagography after ingestion of 250 mL of low-density barium in a patient with liquid dysphagia after Collis gastroplasty and Nissen fundoplication. Anteroposterior three-on-one spot radiographs in upright position (*1, 2,* and *5* = 1, 2, and 5 minutes, respectively) after barium ingestion show poor esophageal emptying.

Figure 7



a. b.

Figure 7: Normal laparoscopic Nissen fundoplication. **(a)** Semiprone (right anterior oblique) esophagram during distended single-contrast phase shows that fundoplication (arrows) primarily surrounds the distal esophagus (arrowhead). **(b)** Spot radiograph of gastric fundus with patient in right lateral 45° erect position shows the leaves of fundoplication (arrows) surrounding distal esophagus and small portion of the stomach (arrowhead). Even appropriately placed fundoplications include small portion of the stomach. This case shows that in normal fundoplication, it is often difficult to completely fill these leaves of the wrap with barium and air.

through the fundoplication. There should not be any substantial delay at this level. Last, gastric motility and emptying should be subjectively assessed. If there is any delay in emptying, the antrum, pylorus, and duodenum are assessed for a morphologic cause of gastric outlet impairment.

Figure 8

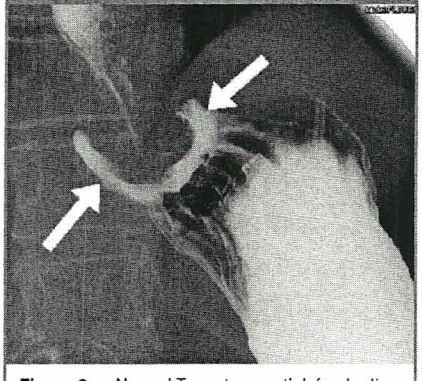


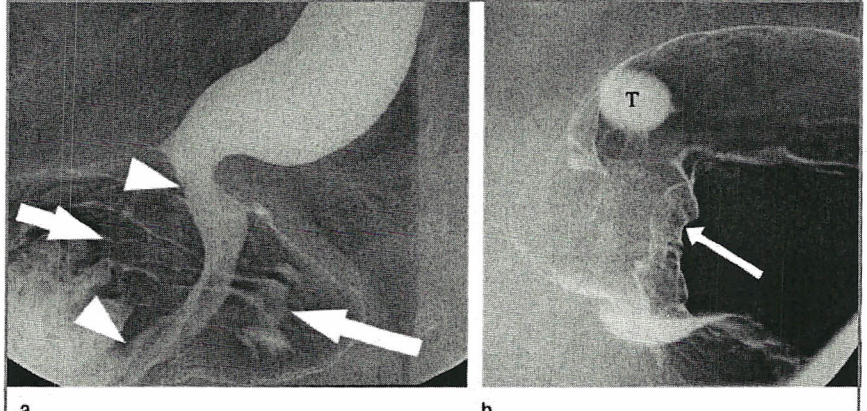
Figure 8: Normal Toupet, or partial, fundoplication. Anteroposterior spot radiograph of gastric fundus in semiupright position after air-contrast portion of esophagography shows that blind-end leaves of the wrap (arrows) are not directly opposed.

Postfundoplication Appearance on the Barium Esophagram

The normal Nissen fundoplication should have the following appearance: it should be subdiaphragmatic with no recurrent hernia above it, it should be less than 3 cm in length, it should surround the distal esophagus with only a small amount of stomach wrapped, it should not obstruct the ingested 13-mm tablet, there should be no reflux, and it should not be twisted. The length of the fundoplication is measured on digital radiographs or is estimated by comparing it to the ingested 13-mm tablet. We can do this on a digital spot radiograph or by grossly estimating it on a videotaped document of the examination. In a normal fundoplication, it is usually very difficult to visualize the anterior blind ends or leaves of the wrap since it is difficult to reflux the barium and gas into this portion of the repair (Fig 7). It is important to know the fundoplication type, since a Toupet, or partial, wrap (<300°) can have the appearance of a disrupted fundoplication (Fig 8).

A variety of findings can be present in a patient with symptoms that generally indicate an abnormal fundoplication. We do not find it helpful to separate abnormal fundoplications into various types, as often they do not fit into discrete categories (48,49). We would rather describe each aspect of the fundoplication. First, it is important to determine the integrity of the fundoplication, whether it is intact or partially or completely disrupted. Then it is important to determine the position of the fundoplication in relation to the diaphragm, whether it is subdiaphragmatic or partially or completely supradiaphragmatic. Then it is important to determine which lumen is wrapped by the fundoplication, whether it is distal esophagus, stomach, or both. When the stomach is encircled by the fundoplication, gastric folds are present and are surrounded by the wrap. The length of fundoplication should be assessed as well. We then determine whether there is a recurrent hernia, which is almost always present when the fundoplication is disrupted. However, in cases of a slipped or malpositioned fundoplication, especially when the esophagus is foreshortened, a recurrent hernia may be present with the fundoplication intact.

Figure 9



a. b.

Figure 9: Long, twisted, tight fundoplication surrounding the stomach in a patient with solid food dysphagia after surgery. **(a)** Semiprone (right anterior oblique) esophagram during distended single-contrast phase shows leaves of fundoplication (arrows) surrounding only gastric folds (arrowheads). Wrap length is at least 4 cm, as estimated when compared with 13-mm tablet. Position of arrowheads roughly approximates superior and inferior extent of fundoplication. Gastric folds surrounded by the wrap do not have straight linear appearance (arrowheads) but a somewhat spiral appearance indicating a twist, which is a very subtle finding and difficult to see. **(b)** Upright anteroposterior spot radiograph of fundus after ingestion of 13-mm tablet *(T)* shows that tablet is obstructed above the level of the wrap (arrow). Poorly coated fundus is seen in lower right quarter.

Pertinent Findings in Patients with Postfundoplication Dysphagia, Epigastric Pain, and Gas Bloat

There are several abnormalities identified in patients with postfundoplication dysphagia or epigastric pain and gas bloat. In our experience, these patients have one or more of the following findings: a tight fundoplication, which impairs the passage of a 13-mm tablet (Fig 9); a long fundoplication, greater than 3 cm, which usually surrounds the medial fundus rather than the distal esophagus (Fig 9); a twisted fundoplication identified by a spiral pattern to the wrapped gastric mucosa; or a partially or completely herniated fundoplication (Fig

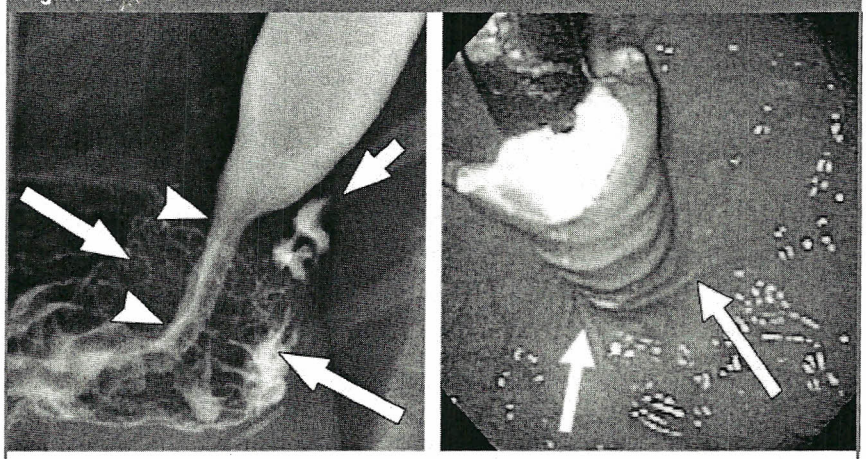
10), which leads to an acquired paraesophageal hernia. On timed barium swallow studies, there may be substantial retention of barium after 5 minutes that mimics achalasia (Fig 6). In our opinion, the cause of these long, tight, and sometimes twisted fundoplications is inadequate mobilization of the gastric fundus with incomplete transection of the short gastric vessels, unless the Rosetti modification of the Nissen fundoplication is used (currently, most surgeons do not use this technique, where fundoplication is created without dividing the short gastric vessels). It is likely that the fundoplication is formed by more medially placed portions of the fundus, and, when formed, it is under tension.

The motility examination is very important in evaluating patients with postfundoplication dysphagia and/or gas bloat syndrome. There are two common motility findings. Some patients show low-amplitude contractions (substantial retrograde escape at the juncture of upper and middle thirds of the esophagus) or aperistalsis. These patients probably had unrecognized poor esophageal motility prior to surgery, with the subsequent fundoplication causing a relative obstruction. Others show normal primary peristalsis to the level of the distal esophagus. At this point, substantial retrograde escape occurs. In these cases, the presence and amplitude of the primary wave are normal but insufficient to overcome the high lower esophageal sphincter pressure caused by a tight fundoplication. This finding complements esophageal manometry, since manometry will not enable identification of this distal retrograde escape. We have confirmed that this finding at barium examination correlates with esophageal impedance, which measures bolus transit (36). Patients with this finding almost always have a long, tight wrap surrounding the stomach and not the distal esophagus.

Pertinent Findings in Patients with Postfundoplication Reflux Symptoms

In patients with recurrent reflux symptoms, several abnormalities can be identified. First, the fundoplication can be disrupted either partially or completely, and in these cases there is usually a recurrent hernia (Figs 11, 12). Second, the fundoplication may be partially or completely disrupted, with herniation of a portion or all of the fundoplication above the diaphragm without a recurrent hiatal hernia (Figs 11, 12). In these cases, the fundoplication has the appearance of a paraesophageal hernia. The fundoplication can be malpositioned and/or it can be a slipped fundoplication with a recurrent hiatal hernia above the fundoplication and/or diaphragm. A slipped Nissen fundoplication is classically thought to be caused by retraction of the esophagus into the chest. This causes the sutures passed from the fundoplication to the anterior wall of the esophagus to break down or pull out. Thus, the fundoplication slips onto the stomach and the fundus is pulled above the fundoplication. We believe that most slipped fundoplications are due to a foreshortened esophagus with inadequate esophageal mobilization during surgery, which results in incomplete reduction of the hernia (Fig

Figure 10



a. b.

Figure 10: Long, twisted, partially supradiaphragmatic fundoplication surrounding the stomach in a patient with dysphagia and gas bloat after surgery. **(a)** Semiprone (right anterior oblique) esophagram during distended single-contrast phase esophagography shows fundoplication (long arrows) surrounding gastric folds (arrowheads). As in Figure 7a, the folds surrounded by the wrap do not have a straight linear appearance but a spiral appearance indicating a twist, which is a very subtle finding and difficult to see. Position of arrowheads roughly approximates the superior and inferior extent of fundoplication. A portion of fundoplication (short arrow) has herniated above the diaphragm in paraesophageal location. **(b)** Retroflexed endoscopic view of fundus shows twist in gastric folds (arrows) caused by the fundoplication.

Figure 11

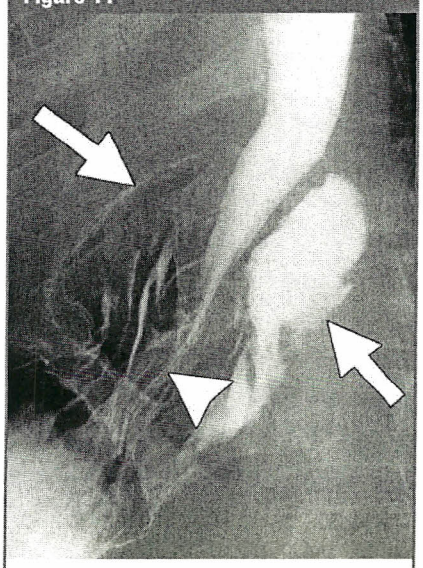
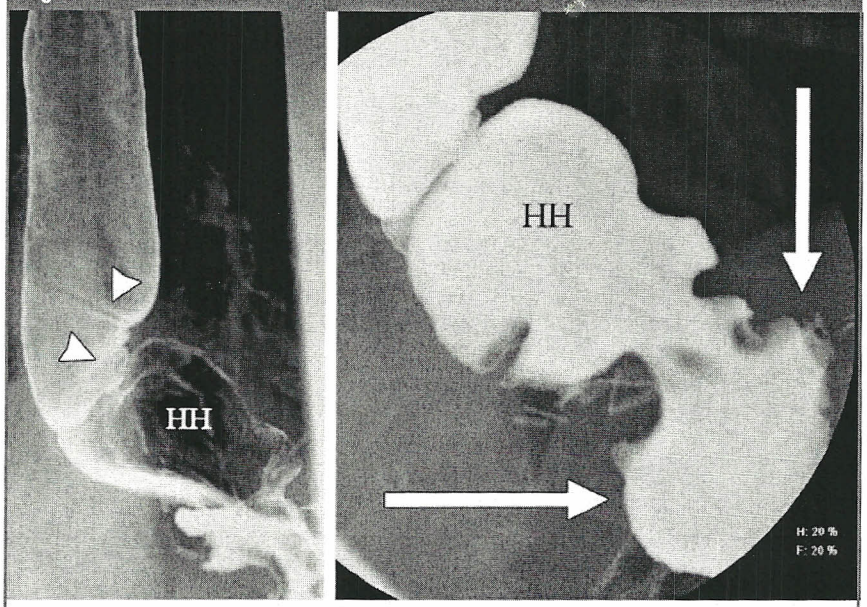


Figure 11: Disrupted supradiaphragmatic fundoplication with small recurrent hiatal hernia in a patient with recurrent reflux symptoms. Semiprone (right anterior oblique) esophagram during distended single-contrast phase of esophagography shows both herniated paraesophageal fundoplication (arrows) and recurrent hiatal hernia (arrowhead).

Figure 12



a. b.

Figure 12: Completely disrupted fundoplication with recurrent hernia in a patient with recurrent reflux symptoms. **(a)** Upright anteroposterior air-contrast esophagram shows that recurrent hiatal hernia *(HH)* does not reduce in upright position. Fixed transverse folds (arrowheads) in distal esophagus suggest longitudinal scarring from reflux esophagitis. The patient likely has a foreshortened esophagus. **(b)** Upright anteroposterior air-contrast esophagram during barium ingestion shows barium-filled distal esophagus, recurrent hiatal hernia *(HH)*, and no fundoplication where one should exist (arrows).

Figure 13

Emptying assessment in patients with liquid dysphagia (timed barium swallow).

Location of the fundoplication vis-à-vis diaphragm.

Lumen encircled by fundoplication (either esophagus, stomach, or both).

Integrity of fundoplication (intact or disrupted).

Length and tightness of fundoplication.

Recurrent hernia and relation to fundoplication.

Esophageal motility.

Gastric emptying and motility (retained food in stomach or depressed peristalsis fluoroscopically).

Figure 13: Issues that should be addressed in an esophagram report in a symptomatic patient after antireflux surgery.

12). After surgery and over time, the esophagus retracts into the mediastinum, resulting in a recurrent hernia. In addition, the fundoplication may be malpositioned and surround the medial portion of the stomach.

Pertinent Findings in Patients with Postfundoplication Nausea and Early Satiety

Patients with postfundoplication nausea and early satiety may have poor gastric emptying caused by a mechanical obstruction, medication, or gastric aperistalsis from vagus nerve injury. Many of these patients have retained gastric secretions and food at the start of the examination. We always ask the patient when he or she last ate, and if food is present, document the presence of food and the time of the last meal. If the patient is not using narcotics, and there is no anatomic cause for gastric outlet impairment and if gastric motility appears depressed, a gastric emptying study is very helpful in further evaluation.

At the end of the examination, our radiology report specifically addresses findings that are pertinent to the gastroenterologist and surgeon. These are summarized in Figure 13.

Conclusion

At our institution, the barium esophagram is an essential part in the care of patients with GERD. Prior to surgery, the examination helps to accurately assess esophageal emptying, identify the presence and type of hiatal hernia and the presence of a foreshortened esophagus, assess motility, and identify the presence of reflux. After surgery, the examination helps assess esophageal emptying in patients with liquid dysphagia; the location, integrity, length, and tightness of the fundoplication; the presence of a recurrent hernia; and motility. The examination also helps subjective assessment of gastric motility and emptying. In many ways, it is the most complete and therefore important examination of the esophagus in patients with GERD.

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