Double-Contrast Upper Gastrointestinal Examination: Technique and Interpretation

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The development of routine double-contrast techniques for examining the upper gastrointestinal (GI) tract has dramatically improved our ability to diagnose a variety of inflammatory and neoplastic diseases in the esophagus, stomach, and duodenum. Despite increasing acceptance of this technique, many radiologists still use conventional single-contrast radiography as the primary modality for examining the upper GI tract. In a recent survey, more than 50% of the responding radiologists at major academic institutions indicated that they did not perform double-contrast upper GI studies on a routine basis (1). In many cases, double-contrast techniques are avoided because of lack of experience or training in the technical aspects of performing or interpreting these studies.

The issue of single- versus double-contrast technique has recently been overshadowed by another, more ominous development in the practice of GI radiology. Data indicate that there has been a gradual but steady decline in the total number of upper GI fluoroscopic examinations performed during the past decade (2,3). This trend can be attributed partly to the increased use of cross-sectional imaging modalities, such as computed tomography or ultrasound, to evaluate GI problems. The greater availability of effective histamine-blocking agents has also changed the clinical approach to patients with dyspepsia or ulcer symptoms, since many of these patients are now treated empirically without further diagnostic evaluation. However, another major factor in the declining number of fluoroscopic examinations is the increasing use of endoscopy as the initial screening study in these patients. This trend has been spurred by a number of correlative radiologic-endoscopic studies from the gastroenterology literature in which endoscopy was found to be a more accurate diagnostic examination (4–6). However, these studies tended to be biased in favor of endoscopy, because the primary authors were usually endoscopists. It also remains unclear whether the ability of endoscopy to depict radiographically missed lesions in the upper GI tract has any significant effect on the management or eventual outcome of the conditions in these patients.

While fiberoptic endoscopy has been recognized as a highly accurate technique for examining the upper GI tract, it is also an invasive technique with a small but measurable risk of gastric perforation or other complications. Furthermore, it is an expensive technique, costing three to four times more in the United States than double-contrast upper GI examinations. Because barium studies are safer and less expensive than endoscopy, radiologic evaluation of the upper GI tract remains a viable alternative as long as its radiologic accuracy approaches that of endoscopy for clinically significant disease. We believe that a carefully performed double-contrast upper GI study provides the best opportunity for radiology to be competitive with endoscopy as a diagnostic modality. A detailed description of the technical aspects of performing and interpreting these examinations is therefore presented.

Technique

The routine double-contrast upper GI examination should be performed as a biphasic study in which both double-contrast and single-contrast views of the esophagus, stomach, and duodenum are obtained. In the double-contrast portion of the study, a series of maneuvers is required to achieve adequate gaseous distention of the lumen while a thin layer of high-density barium is spread on the mucosa. The double-contrast examination is facilitated by the routine use of hypotonic agents. Subsequently, the double-contrast study should be supplemented by prone or upright single-contrast views of the esophagus, stomach, and duodenum obtained with low-density barium and varying degrees of compression. The basic elements of the double-contrast examination, including mucosal coating, gaseous distention, hypotonia, fluoroscopic maneuvers, and a step-by-step approach to the routine examination, are discussed separately in the following sections.

Mucosal Coating

Adequate mucosal coating is achieved in the upper GI tract by flowing a high-density barium suspension over the mucosa. Because mucosal coating depends on the physical and chemical properties of the barium suspension, the choice of barium directly affects the quality of the examination. In general, the best results are obtained with high-density (ie, 200% wt/vol), intermediate-viscosity barium, such as E-Z-HD (E-Z-EM, Westbury, NY) or HD 85 (Lafayette Pharmacal, Lafayette, Ind). Adequate mucosal coating is usually present when a thin, uniform white line is observed with fluoroscopy along the contour of the stomach. The quality of mucosal coating may also be judged on the basis of whether an areae gastricae pattern is visible in the stomach. With standard barium suspensions, however, areae gastricae can be detected in only about 70% of patients (7). Since visualization of these structures depends on multiple factors, including the amount and viscosity of mucus in the stomach, failure to dem-

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onstrate an areaea gastricae pattern does not necessarily indicate that mucosal coating is inadequate.

Food or fluid in the stomach may also interfere with the quality of mucosal coating. Patients are therefore instructed to fast overnight before undergoing a double-contrast examination, in order to minimize the amount of fluid or secretions in the stomach. Patients should also be discouraged from smoking on the day of the examination, as cigarette smoke increases gastric secretions and impairs mucosal coating (8). Nevertheless, some patients with gastric outlet obstruction, gastroparesis, or hypersecretory states may have so much residual fluid or debris in the stomach that adequate mucosal coating cannot be achieved despite these precautions. In such cases, a nasogastric tube may be used to aspirate fluid from the stomach before the examination.

**Gaseous Distention**

Gaseous distention is required to face normal folds, in order to visualize the overlying mucosa. If adequate distention is achieved, the surface features of the mucosa can be assessed both en face and in profile. If distention is inadequate, however, prominent folds may obscure mucosal lesions, and barium trapped between the folds can mimic ulceration. By contrast, overdistention may impair mucosal coating or may obliterate abnormal folds or varices. As a result, spot radiographs should be obtained at varying degrees of distention during the fluoroscopic examination.

The simplest method for introducing gas into the stomach and duodenum is to have the patient swallow effervescent tablets, granules, or powder that rapidly release 300–400 mL of carbon dioxide on contact with fluid in the stomach. Occasionally, however, bubble formation may occur in the esophagus or stomach as an undesirable artifact. Thus, most effervescent agents used for double-contrast examinations contain simethicone, an antifoaming agent, to minimize this problem.

While the stomach and duodenum are readily distended by effervescent agents, the patient must gulp a high-density barium suspension as quickly as possible to achieve adequate gaseous distention of the esophagus. With rapid swallowing, the peristaltic sequence is interrupted, and the esophagus becomes hypotonic. As the patient gulps the high-density barium, swallowed air also distends the esophagus, contributing further to the double-contrast effect. However, some elderly or debilitated patients may only be able to take small sips of barium, so that adequate esophageal distention cannot always be achieved. If esophageal disease is believed to be present, a soft rubber catheter may be inserted into the esophagus and a tube esophagogram obtained by insufflating air through the catheter as the patient swallows high-density barium (9). Similarly, gas may be introduced via a tube in the stomach or duodenum when gaseous distention of these structures is inadequate on routine double-contrast studies in patients who are believed to have disease.

**Hypotonia**

Glucagon is an effective hypotonic agent for double-contrast examinations of the upper GI tract. A standard dose of 0.1 mg administered intravenously produces adequate gastric hypotonia in most patients within 45 seconds of the injection (10). With the use of glucagon to decrease gastric peristalsis, it is possible to obtain better double-contrast views of the antrum and body of the stomach in a relaxed, hypotonic state. Because glucagon also tends to delay gastric emptying, double-contrast views of the stomach can be obtained in most patients before it is obscured by overlapping loops of barium-filled duodenum or small bowel. At the same time, delayed filling of the duodenum may be an undesirable side effect of glucagon, prolonging the examination in some patients. Otherwise glucagon has virtually no side effects, except for the remote possibility of a hypersensitivity reaction. The only contraindications to the use of glucagon are pheochromocytoma, insulinoma, and brittle, insulin-dependent diabetes.

In the evaluation of known gastric lesions (ie, healing of gastric ulcers), larger doses of glucagon (usually 1.0 mg) may be given intravenously to achieve greater levels of gastric hypotonia for a detailed double-contrast examination. Similarly, a hypotonic double-contrast examination may be obtained in patients who are believed to have duodenal disease, by administering 1.0 mg of glucagon to induce duodenal hypotonia after barium has entered the duodenum.

While glucagon is a useful hypotonic agent for the stomach and duodenum, it has no effect on esophageal peristalsis and will not produce better double-contrast views of the esophagus. However, it has been shown that glucagon relaxes the lower esophageal sphincter (11) and therefore increases the frequency of spontaneous gastroesophageal reflux (12). Anticholinergic drugs, such as propantheline bromide (Pro-Banthine; Searle, San Juan, Puerto Rico), may be given to paralyze the esophagus, but these drugs are rarely used because of their many side effects. Another anticholinergic drug, Buscopan (nyoscine N-butyl bromide), produces effective but transient hypotonia of the esophagus, stomach, and duodenum. Because this agent relaxes the pylorus, excellent double-contrast views of the duodenum can also be obtained. While Buscopan is a popular hypotonic agent in Europe, it is not available in the United States.

**Maneuvers**

For performance of the double-contrast examination, a standard set of maneuvers is required to achieve adequate mucosal coating and gaseous distention. The examination must be performed quickly, since overlapping loops of barium-filled small bowel may impair visualization of the stomach and duodenum. The major purpose of fluoroscopy is to determine the volume of barium and gas, to assess mucosal coating, and to insure accurate positioning and timing of spot radiographs. Because the quality of mucosal coating tends to deteriorate rapidly during the fluoroscopic examination, repeated turning of the patient is required to manipulate the barium pool and obtain a fresh mucosal coating at each exposure.

While it is important to develop a standard routine for performance of the examination, additional maneuvers and/ or spot radiographs may be required if an abnormality is suspected at fluoroscopy. When the double-contrast portion of the study has been completed, prone and upright single-contrast views should be obtained with compression to supplement the double-contrast examination. Because careful fluoroscopic positioning of the patient is required, the double-contrast study consists only of fluoroscopic spot radiographs without routine overhead radiographs.

**The Routine Examination**

1. A standard dose of 0.1 mg of glucagon diluted to 0.25 mL with sterile water is given intravenously.

2. The patient swallows one packet of effervescent granules or “fizzies” (ie, E-Z-EM) followed by 10 mL of water.

3. The patient gulps a cup of high-density barium (120 mL) as quickly as possible. The two best barium suspensions for this purpose are E-Z-HD (E-Z-EM) and HD 85 (Lafayette Pharmacal).

4. One three-on-one or two two-on-one upright spot radiographs are obtained in rapid sequence to demonstrate the entire length of the esophagus in a left posterior oblique (LPO) projection (Fig 1a). (All radiographic projections are indicated with respect to the tabletop.)

5. The table is brought to the horizon...
horizontal position with the patient’s back to the tabletop.

6. The patient turns to the right through a 360° circle back to the supine position. If mucosal coating is adequate, a frontal spot radiograph of the stomach is obtained for a double-contrast view of the gastric antrum and body (Fig 1b), since barium pools in the fundus in the supine position. If mucosal coating is inadequate, the patient may be rotated one or more additional turns before obtaining a radiograph. While some barium may spill into the duodenum during this maneuver, 360° rotation of the patient provides optimal coating of all mucosal surfaces of the stomach by the high-density barium. (If the patient cannot be rotated 360° because of age, debilitation, or other reasons, a gentle rocking maneuver can be performed to achieve adequate mucosal coating in most cases.)

7. A spot radiograph of the antrum and body of the stomach is obtained in the LPO position.

8. The patient turns into a right lateral position for a double-contrast view of the gastric cardia and fundus (Fig 1c). This view also permits visualization of the retrogastric area.

9. "Uphill" flow technique is performed by turning the patient onto the back and then slowly into an LPO position. This maneuver causes the barium pool to flow gradually from the antrum toward the body and fundus of the stomach. While the flow of barium is carefully monitored with fluoroscopy, four-on-one spot radiographs of the upper and lower body and antrum of the stomach are obtained. These radiographs are deliberately taken while the posterior wall of the body and antrum are covered by a thin layer of barium, to delineate shallow depressed or protruded lesions (13).

10. With the table in a semiupright position, the patient is turned into a right posterior oblique (RPO) position for a double-contrast view of the upper body and lesser curvature of the stomach. "Downhill" flow technique may also be performed by observing the stomach with fluoroscopy as the patient is slowly turned to the RPO position. This maneuver causes the barium pool to flow from the fundus along the lesser curvature and posterior wall into the body and antrum, better delineating lesions high on the lesser curvature of the stomach. Additional four-on-one

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Figure 1. Normal double-contrast upper GI examination. (a) Upright LPO view of esophagus. (b) Supine view of stomach. (c) Right lateral view of cardia and fundus. (d) Semiupright LPO view of duodenum.
Figures 2, 3. (2) Flow artifact in esophagus. (a) Residual layer of high-density barium obscures mucosal detail in esophagus. (b) Repeat double-contrast view obtained moments later shows reflux esophagitis in distal esophagus, with mucosal nodularity and inflammatory esophagogastric polyp (arrow) not visible on earlier image. (3) Value of prone esophagogram for distal esophagus. (a) Double-contrast radiograph shows no definite abnormality, although distal esophagus is not optimally distended. (b) Prone esophagogram from same examination shows hiatal hernia and adjacent peptic stricture (arrow) not visible on double-contrast image.

spot radiographs may be obtained during this maneuver.

11. By this time, barium usually has emptied into the duodenum. The patient is turned into an LPO position for four-on-one double-contrast spot radiographs of the duodenal bulb and descending duodenum (Fig 1d). If the bulb is inadequately distended with gas or obscured by barium, the table may need to be elevated to a fully upright position. This maneuver causes barium to pool in the antrum or descending duodenum and air to rise into the duodenal bulb, which tends to assume a vertical configuration, so that adequate double-contrast views of the bulb usually can be obtained.

12. An upright LPO spot radiograph of the stomach is obtained for an additional double-contrast view of the fundus.

13. The table is lowered to the horizontal position, and the patient drinks a low-density barium suspension in a prone RAO position. To assess esophageal peristalsis, the patient is instructed to take single swallows of barium, so that the entire peristaltic sequence can be evaluated with fluoroscopy. A single three-on-one or two two-on-one spot radiographs of the esophagus are then exposed during continuous drinking, to permit optimal distention of the distal esophagus and gastroesophageal junction.

14. With the patient in a prone or RAO position, four-on-one spot radiographs of the gastric antrum and duodenal bulb are obtained with varying degrees of compression using an inflatable balloon or other prone compression device positioned beneath the patient's abdomen. These views are important for showing depressed or protruded lesions on the anterior wall of the stomach or duodenum.

15. The patient is turned onto the left side and then onto the back, so that barium pools in the fundus. The gastroesophageal junction is then monitored with fluoroscopy as the patient turns slowly to the right, in order to demonstrate spontaneous gastroesophageal reflux. A straight-leg raising maneuver or Valsalva maneuver can also be performed to elicit reflux.

16. The patient is returned to the right lateral position, and the table is fully elevated for four-on-one upright spot radiographs of the barium-filled stomach and duodenum with varying degrees of compression.

The filming sequence and purpose of each radiograph are summarized in Table 1. With some experience, the fluoroscopist should be able to complete the study in 2–4 minutes of fluoroscopy time and about 10 minutes of room time. When a lesion is suspected at fluoroscopy, the double-contrast examination should be tailored to demonstrate the lesion both en face and in profile. In many cases, flow technique and prone or upright compression views may also be needed to better delineate a suspected abnormality. Ultimately, each radiologist must develop his or her own routine for performing the examination. While individual maneuvers or filming sequences may vary, the end result should be a high-quality double-contrast examination.

Problems and Pitfalls

Esophagus.—Technical factors related to the amount of barium and gas in the esophagus may greatly affect the quality of the double-contrast examination. Because double-contrast radiographs of the esophagus are obtained with the patient in an upright position, pooling of barium in the distal portion of the esophagus may obscure mucosal detail in this region. As barium enters the
stomach, a residual layer of high-density barium in the esophagus may also obscure the mucosa (Fig 2a). When this “flow artifact” is observed at fluoroscopy, however, repeat views obtained moments later should better delineate mucosal lesions as the volume of residual high-density barium on the mucosa decreases (Fig 2b) (14). At the same time, esophageal peristalsis causes the esophagus to collapse almost immediately after passage of the barium bolus into the stomach. The fluoroscopist therefore must time the exposures to capture the esophagus during a relatively brief period of optimal distention and coating. With some experience, it is possible to obtain satisfactory double-contrast views of the esophagus in about 75%–85% of patients (15,16).

When esophageal disease is believed to be present, the cup of high-density barium may be split into two portions for a more detailed double-contrast examination. By having the patient drink half of the barium during the usual LPO projection and half during an RPO projection, protruded or depressed lesions in the esophagus may be evaluated both en face and in profile. Alternatively, a tube esophagogram may be obtained when the routine double-contrast examination is inconclusive (9).

While mucosal disease is best evaluated with double-contrast technique, abnormalities of the longitudinal folds are better seen on mucosal relief views of the collapsed or partially collapsed esophagus. For example, esophageal varices may be effaced or even obliterated by esophageal distention, so that mucosal relief views should be obtained with the patient in the recumbent position whenever varices are suspected on the basis of clinical findings. Various types of esophagitis may also be recognized due to the presence of thickened, irregular longitudinal folds in the collapsed esophagus.

When a ring or stricture is suspected in the distal portion of the esophagus, particular emphasis should be placed on prone single-contrast views of the esophagus during continuous drinking of a low-density barium suspension, to produce optimal distention of the distal esophagus and gastroesophageal junction. Both Schatzki rings and peptic strictures that are not visible on double-contrast radiographs may be detected when the esophagus is maximally distended by means of this technique (Fig 3) (17,18).

Stomach.—The proper volume of barium and gas are required for optimal double-contrast views of the stomach. A 120-mL cup of high-density barium is usually adequate for this purpose. Occasionally, however, barium may empty rapidly from the stomach despite intravenous administration of glucagon. In such cases, additional barium may be given to the patient in a recumbent LPO position to obtain better mucosal coating. Similarly, if the patient belches during the examination, an additional packet of effervescent agent may be required to produce adequate gaseous distention. Conversely, the patient may be asked to belch if the stomach is overdistended with gas, since overdistention may efface abnormal folds associated with ulcers or ulcer scars. Even when the proper amounts of barium and gas are present, retained fluid or debris in the stomach may impair mucosal coating, so that additional turning of the patient is required to wash the mucosal surface and achieve adequate coating.

In patients who are relatively unresponsive to glucagon, rapid emptying of barium into the duodenum may cause portions of the stomach to be obscured by overlapping loops of barium-filled duodenum or small bowel. This overlap may particularly impair visualization of the distal antrum. If it is a frequent problem, the first part of the double-contrast study may be modified so that the table is returned to the horizontal position with the patient facing the table immediately after swallowing the high-density barium suspension. The patient then may be turned from the prone position onto the left side and back in order to obtain unobscured double-contrast views of the distal antrum before barium spills into the duodenum. The usual routine then may be followed for the rest of the examination.

In other patients who are unusually sensitive to glucagon, gastric hypotonia may significantly delay spillage of barium into the duodenum, prolonging the examination. When this problem is encountered, the patient may be asked to wait outside the examining room for 10 or 15 minutes until the glucagon effect has subsided. Since another study can be performed while the patient is waiting, the fluoroscopy schedule need not be delayed by a glucagon-sensitive person.

Most lesions on the anterior wall of the stomach will be shown by the combination of supine double-contrast and prone compression radiographs. For example, a shallow ulcer on the anterior wall may appear as a “ring shadow” on double-contrast views (Fig 4a), but prone compression views of the an-
trum should demonstrate filling of a discrete ulcer niche (Fig 4b). When such lesions are not clearly shown by these routine maneuvers, however, a double-contrast study of the anterior wall can be performed (19). In such cases, the patient is placed in a prone LAO Trendelenberg position. This maneuver causes the barium to pool in the fundus of the stomach with only a thin residual layer of barium on the anterior wall, so that double-contrast views of this region can be obtained.

In patients who have undergone partial gastrectomy (ie, Billroth II operation), the altered anatomy of the stomach requires modification of the routine double-contrast study. The patient initially should be given a larger intravenous dose of glucagon (ie, 1.0 mg rather than 0.1 mg) to prevent rapid spillage of barium through the gastroenterostomy into the proximal small bowel. At the same time, a smaller dose of effervescant agent (ie, half of a packet of "fizzies") is sufficient to achieve adequate gaseous distention of the gastric remnant. Also, the patient should not gulp a full cup of high-density barium, since a large volume of barium in the gastric remnant may obscure mucosal detail in this region. Instead, several swallows of barium in a semiupright position should permit adequate mucosal coating of the anastomosis and gastric remnant (Fig 5). The reader is referred to other articles for a more detailed discussion of double-contrast techniques for examining the postoperative stomach (20,21).

Duodenum.-Once the duodenum has filled with high-density barium, adequate double-contrast views of the duodenal bulb and descending duodenum can usually be obtained by placing the patient in a recumbent, semiupright, or upright LPO position to distend the bulb with gas. When the duodenal bulb is located in a posterior position, the patient may be turned into a left lateral or even a prone LAO position to achieve adequate gaseous distention of the bulb. If, despite these maneuvers, satisfactory double-contrast views of the duodenum cannot be obtained, the fluoroscopist should proceed to the single-contrast portion of the study rather than prolong the double-contrast examination, since it is almost always possible to obtain adequate prone or upright compression views of the bulb.

INTERPRETATION

Normal Appearances

**Esophagus.**—The esophageal mucosa normally has a smooth, featureless en face appearance on double-contrast radiographs. Occasionally, delicate transverse folds may be observed as a transsient phenomenon due to contraction of the longitudinally oriented muscularis mucosa (Fig 6) (22). However, the normal longitudinal folds are usually effaced or obliterated by gaseous distention of the esophagus. While the presence of mucosal nodularity usually indicates an inflammatory or neoplastic process, the mucosa occasionally may have a nodular appearance in some middle-aged or elderly individuals with glycogenic acanthosis, a benign degenerative condition in which there is accumulation of glycogen within the squamous epithelial lining of the esophagus (Fig 7) (23,24).

Stomach.—While the appearance of the rugae in the stomach is important on conventional barium studies, these folds are effaced or obliterated by gaseous distention on double-contrast examinations. Instead, emphasis is placed on radiologic evaluation of the gastric mucosa. With adequate mucosal coating, the normal areae gastricae are usually most prominent in the antrum and body of the stomach. Enlargement or distortion of the areae gastricae may be related to the presence of superficial gastritis, hypersecretory states, intestinal metaplasia, or, rarely, early gastric cancer (25,26). However, further investigation is required to understand better the significance of these variations in the surface pattern of the stomach.

Duodenum.—The duodenal bulb usually has a smooth, featureless appearance on double-contrast radiographs. Occasionally, however, a lacy, reticular mucosal pattern may be observed in the duodenum both en face and in profile due to trapping of barium in normal mucosal pits (Fig 8b) (27). This finding is important because it can be mistaken radiographically for erosive duodenitis.

**Depressed Lesions**

Esophagus.—Double-contrast radiography is particularly valuable for the detection of shallow ulcers and erosions due to various types of esophagitis. In most cases, the underlying cause can be suggested on the basis of the radiographic findings and clinical history. In patients with reflux esophagitis, superficial ulceration in the distal portion of the esophagus may manifest on radiographs as multiple tiny collections of barium on the esophageal mucosa (Fig 9a) (28). Although some patients may have a more diffuse erosive esophagitis involving the distal one-third or two-thirds of the thoracic esophagus, there is almost always a continuous area of mucosal disease extending proximally from the gastroesophageal junction. Thus, the presence of superficial ulceration in the midesophagus with distal esophageal sparing should indicate some other cause for the patient’s
Superficial ulcers predominantly involving the midesophagus are usually caused by herpes or drug-induced esophagitis. In the early stages of herpes esophagitis, double-contrast radiographs may reveal discrete, superficial ulcers clustered together or widely separated by normal intervening mucosa (Fig 9b) (29,30). The ulcers are often surrounded by a radiolucent halo of edematous mucosa. Similarly, drug-induced esophagitis may manifest as one or more discrete areas of superficial ulceration in the mid or, less commonly, distal esophagus, so that differentiation from herpes esophagitis may not be possible on the basis of the radiologic findings (Fig 9c) (31,32). However, a temporal relationship between ingestion of the offending medication (usually tetracycline or doxycycline) and the onset of esophagitis should indicate the correct diagnosis.

Stomach.— Gastric erosions may be classified radiographically as complete or incomplete erosions. Most patients have complete or "varioliform" erosions in which a punctate or slitlike collection of barium is surrounded by a radiolucent halo of edematous mucosa (Fig 10a) (33). Varioliform erosions are most commonly found in the antrum of the stomach and are often aligned on rugae. While no etiologic significance is generally attributed to the shape or location of these gastric erosions, aspirin and other nonsteroidal anti-inflammatory drugs may produce linear or serpiginous erosions that tend to be clustered in the body of the stomach, on or near the greater curvature (Fig 10b) (34). Because these lesions have a distinctive appearance on double-contrast studies, a specific cause for the patient's gastritis can be suggested on the basis of the radiographic findings.

Double-contrast radiography is a valuable technique for diagnosing gastric ulcers and for differentiating benign from malignant lesions (35,36). The majority of ulcers detected on double-contrast studies are less than 1 cm in size (36). While some benign ulcers are round and symmetric (Fig 11a), others may have a rod-shaped or linear appearance. Enlarged areae gastricae are often observed surrounding the ulcer, due to edema and inflammation of the adjacent mucosa (Fig 12a) (36). Subsequent ulcer healing may manifest not only as a decrease in the size of the ulcer but as a change in its shape (Fig 12b). In most cases, ulcer healing produces a radiographically visible ulcer scar with a central pit or depression, radiating folds, and/or retraction of the adjacent gastric wall (36,37). While a residual depression could be mistaken for an active ulcer crater, the central portion of a reepithelialized scar some-
times can be differentiated from an active ulcer by the presence of normal areae gastricae within the scar (Fig 11b) (36).

**Duodenum.**—**Erosive** duodenitis is diagnosed less frequently than erosive gastritis on double-contrast studies because of the difficulty in differentiating duodenal erosions from normal mucosal pits (27). However, erosive duodenitis can be diagnosed when double-contrast radiographs reveal one or more varioliform erosions in the proximal duodenum (Fig 13).

Unlike gastric ulcers, which occur primarily on the posterior wall of the stomach, as many as 50% of duodenal ulcers are located on the anterior wall (38). Since most double-contrast radiographs are obtained with the patient in a supine or supine oblique position, the anterior wall of the duodenum is not optimally coated with barium, so that anterior wall ulcers may be missed on the double-contrast portion of the study. For this reason, double-contrast views of the duodenum should be supplemented by prone compression views obtained with a low-density barium suspension to demonstrate ulcers on the anterior wall (38). In other patients with anterior wall ulcers, a "ring shadow" may be detected on double-contrast radiographs due to a thin coating of barium on the rim of a nondependent ulcer. In such cases, the ulcer can almost always be filled with barium and diagnosed definitively on prone or upright compression views of the duodenum. Thus, biphasic technique is particularly important in the evaluation of this area.

**Protruded Lesions**

**Esophagus.**—**Candida** esophagitis usually manifests on double-contrast radiographs as discrete plaquelike lesions with intervening segments of normal mucosa (Fig 14) (39). Because the lesions have well-defined borders, they may be etched in white by a thin layer of barium trapped between the edge of the plaque and the adjacent mucosa. Glycogenic acanthosis may also produce plaquelike lesions indistinguishable from those of Candida esophagitis (Fig 7) (23,24). However, most patients with glycogenic acanthosis are asymptomatic, so that these conditions usually can be differentiated on the basis of clinical findings.

Early esophageal cancers classically appear on radiographs as small protruded lesions less than 3.5 cm in diameter (40). They may be plaquelike lesions (often with central ulceration) or flat, sessile polyps with a smooth or slightly lobulated contour (Fig 15a) (40). Other early cancers may be superficial spreading lesions, causing localized nodularity or granularity of the mucosa (Fig 15b) (40). When a suspicious lesion is detected on double-contrast radiographs, endoscopy and biopsy should be performed for a definitive diagnosis.

**Stomach.**—Early gastric cancers may be elevated, flat, or depressed lesions. The Japanese have developed an elegant system for classifying these cancers based on the predominant morphologic features of the lesion (41). Elevated lesions may be plaquelike or polypoid and occasionally may occupy a considerable surface area of the stomach without invading beyond the submucosa. Unfortunately, most patients...
in the United States with gastric carcinoma already have advanced lesions at the time of clinical presentation, so that early gastric cancer is unlikely to be detected on double-contrast studies as long as these examinations are performed predominantly on symptomatic patients (42).

Duodenum—Heterotopic gastric mucosa in the duodenal bulb is observed as a relatively frequent finding on double-contrast examinations of the upper GI tract. This abnormality is characterized on double-contrast radiographs by angulated or polygonal 1-5-mm filling defects that tend to be clustered near the base of the bulb (Fig 16) (43). By contrast, hyperplastic Brunner glands and prominent lymphoid follicles in the duodenum may manifest as multiple round, uniformly sized, 2-3-mm nodules in the bulb and proximal duodenum (43). While diffuse lymphoid hyperplasia of the duodenum and small bowel is often associated with immunoglobulin deficiency states, isolated lymphoid hyperplasia of the duodenum may be observed in patients who have no underlying disease.

References
