This review article presents the principles for performing a safe, comfortable, and accurate double-contrast barium enema examination. The procedure is a flexible examination in which the fluoroscopist interacts with the patient, the controls of the fluoroscope, and the image on the television monitor. During a double-contrast examination, images of the colon are created by manipulating the patient, the barium pool, and the amount of air insufflated into the rectum. Fluoroscopy is essential for guiding the radiologist to obtain spot images with adequate technical factors. The fluoroscopist analyzes the luminal contour, the barium-coated mucosal surface en face, and the barium pool to detect abnormalities in the colon. With careful technique, a high-quality examination can be performed in most patients.

The recent focus on colonic cancer screening has renewed interest in the double-contrast barium enema examination and has stimulated the writing of this article as one of a four-part series on colonic imaging. The purpose of this review article is to describe and illustrate general concepts in the performance of a high-quality double-contrast barium enema examination.

The double-contrast barium enema examination has existed in one form or another since the 1920s and 1930s (1–5). The double-contrast barium enema examination technique was still in its infancy in the 1940s and 1950s but improved dramatically in the 1960s and 1970s with improvements in preparation of the patient, enema tube tips, and coating properties of high-density barium (6–9). Today, there are numerous textbook descriptions of the barium enema examination technique (10–18). As there are more ways to perform a barium enema examination than there are radiologists, we will describe the principles of performing a safe, comfortable, and accurate double-contrast barium enema examination only as performed at the Hospital of the University of Pennsylvania (19). We will provide the rationales for the components of our “tailored” double-contrast barium enema examination.

PREPARATION FOR BARIUM ENEMA EXAMINATION

The patient must be prepared both physically and mentally to undergo a barium enema examination. Both the radiologist and the patient’s physician take an active part in the preparation of the patient. The radiologist provides simple, readable instructions for the colonic preparation. The radiologist also provides a brief written description of the examination. The written description of the study and a verbal description of the examination by the referring physician will help alleviate patient apprehension about undergoing a barium enema examination.

Numerous physical preparations have been described and tested scientifically (20–38). The plethora of preparations reflect the inability to achieve a clean colon in all cases. Success in colon cleansing is often a function of patient understanding and compliance with the preparation, as well as of the patient’s own baseline colonic motility. Most preparations are successful in young, healthy, mobile outpatients. Colonos in patients with colonic hypomotility, however, may be difficult to clean completely. This group includes patients who are bedridden, patients with motility disorders such as diabetes or scleroderma, and patients taking opiates or drugs with anticholinergic side effects. In patients in whom colonic hypomotility is suspected, a prolonged low-residue diet, a full 2-day preparation, or cleansing enemas may be of value.

Most preparations include a low-residue diet for 1–3 days prior to the examination, a
solution that keeps enteric contents semifluid, and an orally administered agent that stimulates colonic contraction. Patients must drink copious liquids (more than 2.0 L) to minimize the dehydration caused by the preparation. In some regimens, a cleansing enema (colonic lavage) is performed.

We use a 24-hour preparation that includes a low-residue diet, magnesium citrate, bisacodyl tablets, and a bisacodyl suppository. Other preparations may be equally effective. However, we do not recommend the use of large-volume (4.0-L) isotonic lavage agents, such as PEG-3350 and electrolytes for oral solution (GoLYTELY; Braintree Pharmaceuticals, Braintree, Mass), as they leave excess fluid in the colon and impair mucosal coating in many patients (28,29).

The referring physician must prepare the radiologist and the patient. The requisition slip for the examination should state the appropriate clinical history, surgical history, and medications the patient takes that have colonic side effects or may cause colonic disease. The referring physician should state if a recent endoscopic intervention has been performed, because there should be a 1-week interval between barium enema examination and performance of large-forceps biopsy through a rigid sigmoidoscope, snare polypectomy, or hot biopsy (39,40). These endoscopic interventions may tear the colonic mucosa and result in a small risk of perforation if a barium enema examination is performed immediately after the endoscopy. Performance of a small-forceps biopsy through a flexible sigmoidoscope or colonoscope does not preclude performance of barium enema examination on the same day.

**MATERIALS**

**Fluoroscope**

In our practice, we use both digital and conventional fluoroscopes. In the digital units, the images can be obtained rapidly and reviewed immediately, which shortens the procedure time by about 10 minutes (41). The use of digital radiography also allows the technologists to spend all of their time attending to the patient, not to changing film cassettes. The digital spot images are reviewed while the technologist obtains overhead radiographs, which allows the radiologist to realign areas in question before the patient is sent to the bathroom.

A washable pad covered by a sheet is placed on the fluoroscopy tabletop. The pad alleviates some patient discomfort, as the bony protuberances of ribs and pelvis rub against the fluoroscopy tabletop.

**Insertion of the Enema Tube Tip**

A digital examination of the anal canal and distal rectum before insertion of the enema tube tip is helpful (42). The digital examination allows for evaluation of hemorrhoids, masses, or inflammatory conditions that may make insertion of the enema tube tip painful or even dangerous. Digital examination also permits the radiologist to assess sphincter tone, which acts as a guide to whether the retention balloon will need to be inflated. The radiologist should wear a nonlatex glove, as anaphylactic reactions to impurities in latex have been reported (43).

A thin layer of lubricant is spread on the enema tube tip. A lubricant containing lidocaine hydrochloride may alleviate pain in patients with hemorrhoids or inflammatory conditions. The enema tube tip is pushed gently through the anal sphincter. If there is any difficulty with enema tube tip insertion, a wide-bore, nonlatex, Foley-type catheter may be used, because it is softer and of a smaller diameter than the standard Miller air tip (44).

Routine distention of the retention balloon is not necessary, as use of the balloon is associated with a small but finite risk of rectal tear or abrasion and an increased risk of hemorrhoidal bleeding (45). Encouraging patients to retain the air and barium is usually sufficient. Retention balloons are inflated only in patients who are expelling air and barium from the anal canal and only after a normal distal rectum is demonstrated fluoroscopically.

Relative contraindications to the use of the retention balloon include pelvic irradiation, various colitides, solitary rectal ulcer syndrome, large distal rectal mass, suspected rectovaginal fistula, and previous anal canal surgery. If inflated, the balloon is distended not to coapt the distal rectal walls but to act as a ball valve that will be pulled back against the anal canal.

**Agents for Colonic Hypotonia**

We routinely use glucagon to induce colonic hypotonia. One milligram of glucagon is slowly injected intravenously during a 1-minute period. The intravenously administered glucagon works in 1 minute and lasts about 10-20 minutes. Intravenously administered glucagon decreases discomfort during barium enema
The mucosal surface en face. Close-up view from a spot radiograph of the sigmoid colon shows a 1.9-cm polypoid adenocarcinoma in a 68-year-old man with right upper quadrant pain and subsequently proved liver metastases. The mass is manifested as a barium-etched hemispheric line (solid arrows) surrounding tiny radiolucent tumor nodules outlined by barium in the interstices of the tumor; representative nodules are identified by the open arrow. The normal mucosal surface is featureless and gray.

Figure 2.

Figure 3. Polyp demonstrated in barium pool. (a) Spot radiograph obtained with the patient in a left-side-down position (left lateral view) shows the rectum early in the examination. At the edge of the barium pool, there is a 7-mm lobulated radiolucent filling defect (arrow). The enema tube tip obscures the distal rectum. (b) Spot radiograph obtained with the patient in a right-side-down position (right lateral view) shows the rectum after enema tube tip removal. The polyp is not depicted definitively. The distal rectum is no longer obscured by the enema tube tip. This polyp is a tubular adenoma.

We compared the anticholinergic agent hyoscine N-butylbromide (Buscopan) with glucagon. Results in patients with known pheochromocytoma, as it could elevate blood pressure related to catecholamine release. We traditionally have instilled barium into the rectum while the patient lies in the prone position. In patients suspected of having disease involving the anterior wall of the rectum or rectosigmoid junction, the patient should be examined first in the lateral position. Thus, in patients suspected of having rectovaginal fistula, endometriosis, or intraperitoneal metastases, we start barium instillation with the patient in the left-side-down lateral position. The enema tube is opened only partly, as rapid distention of the rectum with barium increases the urge to defecate. The patient can be turned in various positions to facilitate passage of the barium through the colon. In general, turning the patient to the left anterior oblique or left-side-down position moves barium into the proximal sigmoid colon, descending colon, and splenic flexure. Placing the patient in a slight Trendelenburg position aids passage of barium into the splenic flexure. Once a full column of barium reaches the apex of the splenic flexure, turning the patient to the prone position will move barium into the middle of the transverse colon. During this time, the radiologist uses fluoroscopy only briefly but carefully analyzes colonic contour and looks for filling defects in the barium pool. If an abnormality is seen while barium is filling the colon, a spot radiograph is obtained.

A large enough volume of barium is required to scrub and coat the colon. If about one-third of the luminal diameter of distended colon is filled with barium, as demonstrated on radiographs obtained with the patient in the decubitus posi-
where it crosses the spine. Once the barium reaches the middle of the transverse colon, hepatic flexure, ascending colon, splenic flexure, descending colon, sigmoid, and rectum are obtained. The size, shape, position, and overall architecture of the colon are shown on overhead images, large (14 × 14-inch) spot radiographs, or large-field digital images. Each colonic segment is viewed in detail on spot radiographs or mid- to high-magnification digital images. The luminal contour is seen in profile either as a continuous barium-etched white line or as a continuous white edge of the barium pool (Fig 1a). With air contrast, the normal mucosal surface is seen en face as a smooth gray surface. With some barium preparations, or when the colon is slightly collapsed, the innominate groove pattern is demonstrated (54,55). Elevated lesions may be manifested as filling defects in the barium pool and alterations of its smooth edge. The goal is to demonstrate each surface of the colon, both with air contrast (Fig 2) and with the barium pool (Fig 3), by using the strengths of their properties to analyze the colonic surface.

A double-contrast examination emphasizes the use of fluoroscopy to obtain spot images. Before obtaining a spot image, barium is allowed to flow across the mucosal surface, the patient is turned to eliminate most of the barium pool, and then a spot image is obtained. Fluoroscopic guidance allows the radiologist to assess and optimize the technical components of luminal distention, bowel loop projection, and mucosal coating. With overhead radiographs obtained by the technologist, there is little control over precise positioning, luminal distention, or mucosal coating. Therefore, the barium enema examination that emphasizes spot images is inherently superior to the examination that emphasizes overhead radiographs (Fig 4).

Once barium is instilled and air is insufflated, the radiologist must be flexible yet compulsive. The order in which the spot images are obtained is relatively unimportant and is flexible, as long as each loop of colon has adequate barium coating and distention and is demonstrated en face. Compression is often helpful to splay apart loops and analyze fluoroscopic findings. In general, we obtain spot images in this approximate order: sigmoid colon, rectum, descending colon, splenic flexure, transverse colon, hepatic flexure, ascending colon, and cecum.

The major technical pitfalls are obscuring one loop with an overlap by another loop and inability to fill the right side of the colon. If barium refluxes through the ileocecal valve before images of the sigmoid colon are obtained, the sigmoid colon may be obscured by barium in the distal ileum. Therefore, at least two exposures of the sigmoid colon are obtained first to ensure that the sigmoid colon is imaged before barium reaches the cecum.
In general, the patient is turned to the right-side-down position to move barium into the hepatic flexure, then onto the back to move barium into the proximal hepatic flexure and ascending colon. To move barium into the proximal ascending colon and cecum, the patient is turned to a left-side-down or semierect position. There is no such thing as “air block,” a situation in which a colon distended by air prevents further passage of barium (56), because barium is much heavier than air and will fill any dependent space. If there is difficulty moving the barium pool into the right side of the colon, it usually means there is not a large enough volume of barium.

When attempting to manipulate the barium pool, the radiologist balances the patient’s ability to turn on the fluoroscopy table with the quality of the barium coating that is being achieved. In toto, the patient is rolled 360° anywhere from one to four times, usually in partial turns. If a patient is elderly or feeble and has difficulty turning, the study should be converted to a single-contrast barium enema examination. Most patients can accomplish two to three complete turns on the fluoroscopy table, which is sufficient for adequate colonic scrubbing and coating.

The colon is viewed in various degrees of luminal distention. The lumen should be distended sufficiently so that the interhaustral folds are straight and oriented perpendicular to the longitudinal axis of the bowel. The rows of teniae coli are at the edges of the haustral sacculations and should be separated by about 2–3 cm (Fig 5). Colonic overdistention is painful, has a small but finite risk of perforation, and may efface plaquelike lesions. Conversely, colonic underdistention may hide even large lesions.

The enema tube tip may be removed after an adequate amount of air and barium has reached the right side of the colon. Early enema tube tip removal provides psychological and physical relief for the patient (57). Early enema tube tip removal is possible in young, mobile patients with good rectal tone. The enema tube tip should be left in place in patients who are expelling gas and in patients who may need additional air to distend the terminal ileum. We usually remove the enema tube tip at the end of the fluoroscopic portion of the examination (58), if not earlier, so we can obtain spot images of the distal rectum, an area that is obscured by the enema tube tip and often difficult to depict at endoscopy, even in retroflexion.

The proximal rectum may be imaged early, before enema tube tip removal, with the patient in both the prone and lateral positions (Fig 3). With the patient in the prone position, the barium pool and enema tube tip obscure the distal rectum. After the enema tube tip is removed, air-contrast views of the distal rectum are obtained with the patient in the supine position. Another lateral view of the rectum is also obtained, but opposite to the one obtained previously, to place the barium pool opposite to that in the first lateral rectal view (Fig 3).

The rectosigmoid junction may be obscured by overlapping sigmoid loops. A
lateral patient position is often best to view this region. In addition, the overhead view obtained with the tube angled about 30° caudad and with the patient in the prone position usually displays the rectosigmoid junction (Fig 6). An angled view also may be obtained with a remote-control fluoroscope capable of tube angulation.

The sigmoid colon is easy to image when it is short and without diverticulosis. However, the radiologist must use every trick of the trade to depict a redundant sigmoid colon involved by moderate to severe diverticulosis. Radiologic techniques to improve depiction of the sigmoid colon include the use of compression (Fig 7), even with the patient in the prone position, and placing the patient in the prone (Fig 8), erect, or Trendelenburg position. The proximal sigmoid colon often is best viewed with the patient in the prone or left posterior oblique position (Fig 9a); the distal sigmoid colon often is best displayed with the patient in the supine or right posterior oblique position (Fig 9b). The most caudal loop of sigmoid colon often is best seen with air contrast with the patient in the prone position (Fig 8).

Views obtained with the patient erect are helpful for removing the barium pool. Extensive use of images obtained with the patient erect may obviate the use of overhead images obtained with the patient in the decubitus position (59), especially in fluoroscopy rooms in which cross-table views cannot be obtained. Views obtained with the patient erect should not be confined to the hepatic and splenic flexures but are also useful in the middle of the transverse colon (Fig 5), a tortuous sigmoid colon, the ascending and descending colon, and even the rectum.

The table is elevated slowly and is stopped three to four times to allow the patient to attain equilibrium. When using a conventional fluoroscope, the radiologist places a hand on the patient’s shoulder as a reassurance that he or she will not fall. When the fluoroscopy table-top is tilted to the erect position, the radiologist must be wary of the patient having a vasovagal reaction. If the patient feels light-headed or faint, closes his or her eyes, or stops communicating, the radiologist should return the table toward the horizontal and carefully evaluate the patient’s clinical status.

The proximal and middle sections of the descending colon often are viewed best with air contrast with the patient in the erect or prone position. The distal descending colon often is viewed best with the patient in the recumbent supine or oblique position (Fig 9). The splenic flexure is viewed best with the patient in an erect (Fig 10) or recumbent (Fig 11) right posterior oblique position. Women are instructed to elevate the left breast manually from the radiation field to decrease radiation exposure to the breast and prevent the soft-tissue shadow of the breast from overlying the splenic flexure.

A spot image should be obtained for every loop in the middle of the transverse colon. Whereas views obtained with the patient in the erect position are superb for the upper two-thirds of the lumen (Fig 5), images obtained with the patient in the supine position better depict the inferior one-third. The hepatic flexure is imaged with the patient in the erect left posterior oblique position (Fig 12). Sometimes the medial wall is demonstrated best with the patient in the supine posi-

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Figure 8. Prone versus supine position for viewing the sigmoid colon and rectum. (a) Spot radiograph obtained after enema tube tip removal with the patient in a supine position. The distal rectum is seen in air contrast. The most caudal loop (arrow) of sigmoid colon is filled with barium. (b) Spot radiograph obtained with the patient in a prone position, but the radiograph is printed in the same anatomic position as a to allow direct comparison of images. Barium in the distal rectum now obscures en face mucosal detail. The most caudal loop (arrow) of sigmoid colon is now seen with air contrast. (a and b reprinted, with permission, from reference 19.)

Figure 9. Spot radiographs of the sigmoid colon with the patient in (a) a left posterior oblique position and (b) a steep right posterior oblique position. Identical segments of the sigmoid colon are identified by similar arrows. Changing the position of the patient changes the location of the barium pool and allows depiction of different segments of bowel en face.
tion. Again, women are instructed to elevate the right breast manually from the radiation field.

The most distal part of the ascending colon often is viewed best with the patient in the erect left posterior oblique position. The proximal ascending colon often is viewed best with the patient in the supine or Trendelenburg position. Images of the cecum often are obtained by using compression. The lateral half of the cecum may be viewed best with the patient in the left posterior oblique position; the medial half of the cecum may be seen better with the patient in the right posterior oblique position (Fig 4a). If there is too much barium in the cecum, the patient may be rolled to the right in the Trendelenburg position, to move barium into the ascending colon, then turned back to the left while still in the Trendelenburg position. If this maneuver does not work, excess barium may be removed from the cecum by rolling a nimble patient 360° toward the right while keeping the patient in a Trendelenburg position. The cecum also should be viewed either fluoroscopically or on spot radiographs with the patient in the prone position, while the anterior wall is bathed in the barium pool.

Demonstration of the appendix, ileocecal valve, or terminal ileum means the...
right side of the colon has been depicted completely. Filling of the appendix and terminal ileum is helpful in patients with right lower quadrant pain and diarrhea, respectively. Appendiceal and terminal ileum filling often best occur before the cecum is fully distended with air. By using manual compression, barium may be pushed into the appendix or terminal ileum, particularly with the patient in the erect or left posterior oblique position. Because the ileocecal valve usually is located on the posterior and medial cecal wall, placing the patient in the prone position often will result in reflux of air into the terminal ileum.

OVERHEAD RADIOGRAPHS AND POSTEVACUATION IMAGES

Overhead images provide the "big picture" and help piece together the spot images. Overhead images are inherently inferior in projection and distention but are superior in minimizing magnification. Barium coating visible on the overhead images may be superior if barium coating at fluoroscopy was thin owing to a large original amount of intraluminal fluid. The added time between spot radiographs and overhead images allows additional turning of the patient and colonic absorption of intraluminal water, which improves coating in some patients. In other patients, however, the late timing of overhead images may lead to barium flocculation.

We believe that the most important overhead radiographs are the images obtained in projections that the radiologist cannot obtain at fluoroscopy: the left (Fig 13) and right (Fig 14) side-down decubitus views and the prone-angled view of the rectosigmoid junction (Fig 6b). We also obtain a view of the abdomen with the patient in the prone position and a cross-table lateral view of the rectum with the patient in the prone position (Fig 15). Overhead images are not obtained routinely with the patient in the supine or oblique position, because these positions already have been imaged extensively on spot radiographs.

Postevacuation overhead images are not obtained routinely. However, postevacuation fluoroscopic images and spot radiographs may be obtained to demonstrate delayed barium filling of tracks in patients suspected of having diverticulitis or fistula. If the appendix or terminal ileum has not been filled with barium but should be imaged for diagnostic reasons, postevacuation fluoroscopy sometimes reveals filling of these structures.

SUMMARY

The double-contrast barium enema examination has as much potential in detecting early cancers and precursor lesions as any radiologic examination, including mammography (60). Performance of a high-quality double-contrast barium enema examination requires a radiologist who aggressively manipulates the patient and barium pool yet is responsive to what is happening on the fluoroscopy table and television monitor. This requires a combination of compulsive scientist and barium artist, ready to tailor the examination to the clinical history, patient, and fluoroscopic findings.

References

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