CT Enterography: Concept, Technique, and Interpretation

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The assessment of small bowel abnormalities has traditionally been a challenging task for radiologists and gastroenterologists. Conventional radiologic and endoscopic evaluations are frequently hindered by the length and caliber of small bowel loops.1 Although, CT in its conventional form has played a significant role in the evaluation of extraenteric manifestations of small bowel disease, it has a limited role for depicting bowel wall and luminal abnormalities.2 CT enterography, a robust new method for evaluating the small bowel, is a byproduct of the recent advances in multidetector-row CT (MDCT) technology.3,4 New MDCT scanners, with isotropic image acquisition in a single breath-hold, allow high-resolution multiphasic assessment of the bowel in multiple planes.4 CT enterography uses this technology to provide a detailed evaluation of the mural features of the gut and its lumen. Additionally, it permits an accurate depiction of the perienteric tissues, thus improving assessment of the disease extension and complications.5 Multiplanar reformations, obtained from isotropic data sets, allow radiologists to evaluate the entire abdomen in planes that facilitate visualization of the pathology.6

In this article, we discuss the advantages of CT enterography over conventional and newer small bowel imaging modalities. Image acquisition and interpretation for the most common indications are also discussed.

CONCEPT

A wide variety of methods are available for the assessment of the small bowel, attesting to the difficulty of evaluating this organ. The current methods of small bowel evaluation include radiologic as well as endoscopic techniques.7 The radiologic armamentarium includes barium studies (small bowel follow-through [SBFT] and enteroclysis), CT techniques (“routine” CT, CT enterography, and CT enteroclysis), ultrasound, nuclear medicine, and MR (MR enterography and MR enteroclysis). Endoscopic methods include ileoscopy, push enteroscopy, double-balloon endoscopy, and wireless capsule endoscopy.7 CT enterography and wireless capsule enteroscopy are two of the most robust imaging techniques with proven efficacy.8

CT enterography combines isotropic-voxel acquisition with the oral intake of large volumes of neutral contrast agents and rapid intravenous administration of iodinated contrast to improve visualization of the small bowel wall and its mural features.9 Misregistration artifacts due to respiratory motion and small bowel peristalsis are effectively eliminated because data is acquired in a single breath-hold.6 The acquired data can then be used to perform excellent two- and three-dimensional reformations, producing high-resolution images of the bowel and mesenteric vessels.10,11 Moreover, the combined use of intravenous and neutral enteric contrast agents optimizes luminal...
distension and depicts attenuation differences among the bowel wall layers, the fluid filled lumen, and the adjacent mesenteric fat.\(^4,5\)

The advantages of CT enterography are its non-invasiveness, its ready availability, and its operator independence. The American College of Radiology Appropriateness Criteria (2005) rates CT enterography as the most appropriate radiologic method in the evaluation of initial presentation or known Crohn disease with acute exacerbation or suspect complications.\(^12\) CT enterography can also play an important role in evaluating obscure gastrointestinal bleeding and in detecting small bowel tumors.\(^5,13\)

CT enterography has several advantages over SBFT study. While SBFT is both operator dependent and limited by deep pelvic and overlapping small bowel loops, CT enterography is not affected by these limitations (Fig. 1). The most distal portion of the terminal ileum is difficult to assess with SBFT but readily evaluated by CT enterography. However, a potential drawback of CT enterography is its higher effective radiation dose when compared with SBFT study.\(^14\)

CT enterography should be distinguished from CT enteroclysis. In CT enterography, the patient drinks a large volume of oral contrast in a short period of time. CT enteroclysis, on the other hand, requires intubation of the descending duodenum or jejunum and administration of enteric contrast material, preferably by a pump, to obtain optimal distension of the small bowel.\(^15\) More reliable distension of the small bowel can be achieved with CT enteroclysis because oral contrast agent is administered by the radiologist.\(^15\) The patient is usually sedated for enteroclysis, leading to increased cost and acquisition time as well as reduced availability.\(^4,15\) A feasibility study by Wold and colleagues\(^7\) comparing CT enterography to CT enteroclysis did not find significant differences in bowel distension and demonstrated similar accuracy in indentifying active Crohn disease for both methods. However, there are no large studies comparing CT enterography to CT enteroclysis.

Although wireless capsule endoscopy is the most sensitive technique for small bowel mucosal evaluation, it has several limitations.\(^7,8\) Its higher sensitivity compared with CT enterography is accompanied by its lower specificity.\(^7,16\) Solem and colleagues\(^16\) comparing different imaging modalities to detect active Crohn disease, did not demonstrate significant difference in sensitivity and accuracy in disease diagnosis among CT enterography, wireless capsule endoscopy, ileocolonoscopy, and SBFT. The sensitivity for identification of active disease was 83\% for CT enterography, 83\% for wireless capsule endoscopy, 74\% for ileocolonoscopy, and 65\% for SBFT. However wireless capsule endoscopy had lower specificity (53\%) and could not be performed in 17\% of patients because of an asymptomatic stricture diagnosed by CT enterography.

Wireless capsule endoscopy also has several technical limitations. Retention of the capsule is a serious risk that requires surgical treatment. Cheifetz and colleagues\(^17\) reported a 13\% risk for capsule retention in patients with known Crohn disease and 1.6\% in those with suspected Crohn disease. The retention rate is 0.7\% to 2\% in patients with obscure gastrointestinal bleeding.\(^8,18\) Additionally, wireless capsule endoscopy generates several thousand images, requiring long interpretation times. Accurate localization of disease

Fig. 1. CT enterography (A) shows segmental mural thickening and hyperenhancement of an ileal loop (arrows) and acute colonic inflammation (arrowheads). SBFT (B) performed in the same patient cannot evaluate the overlapping small bowel loops (small arrows) in the pelvis or the colon.
may be difficult by wireless capsule endoscopy.19 Also, the evaluation of the small bowel may be incomplete because of fast transit, presence of hemorrhage, or failure to reach the cecum.8 A patency wireless capsule that dissolves automatically can also be used to ensure safe subsequent usage of wireless capsule endoscopy.

The role of MR in the diagnosis and follow-up of small bowel pathology remains limited at this time. The development of fast imaging sequences has improved the quality of MR imaging. However, MDCT scanners have a superior spatial resolution.20 In a prospective study comparing CT and MR enteroclysis for the evaluation of Crohn disease, CT showed higher interobserver agreement and superior sensitivity in detecting signs of active disease.20 Albert and colleagues21 reported sensitivity of 78% for MR enterography compared with 93% for wireless capsule endoscopy. Masselli and colleagues22 reported similar performance for MR enterography and MR enteroclysis in Crohn patients. Radiation exposure in CT enterography will likely be a catalyst for further research and acceptance of MR enterography.

**TECHNIQUE**

When assessing the small bowel with CT enterography, attention to patient preparation and image acquisition techniques is essential. The study should be tailored to answer the question at hand and to optimize visualization of the mural features of the gut. The amount and timing of neutral oral contrast affects the degree of distension. The timing and rate of intravenous contrast administration determines the degree of bowel wall enhancement.23,24 High spatial resolution and multiplanar reformations are essential for displaying the pathology.25

**Small Bowel Distension**

Adequate bowel distension is of utmost importance in CT enterography. Collapsed or poorly distended bowel loops can obscure pathologic processes and even simulate bowel wall thickness and mucosal hyperenhancement.25,26 Slow administration of a large volume of oral contrast within a short time is required to achieve bowel distension.6 The oral contrast agents used for CT enterography can be categorized into two groups: positive contrast agents and neutral contrast agents.25 Positive contrast agents, such as iodine solution and barium suspension dilute, have high attenuation values and are routinely used to delineate the intestinal tract in CT.4 In fact, CT enterography was initially described with the use of positive contrast agents.4,27 However, positive contrast agents are not ideal for the evaluation of bowel pathology for several reasons.5,10,25 They limit the visualization of the mural features of the intestinal tract.4,5 When assessing for obscure gastrointestinal bleeding, the high attenuation of these contrast agents obscures the source of hemorrhage. Small bowel neoplasms typically enhance with intravenous contrast material. However, this feature cannot be easily assessed when high-density enteric contrast is present.13 Additionally, positive contrast agents may interfere with the postprocessing techniques and hinder visualization of the mesenteric vessels.25,28 However, when intravenous contrast material cannot be administered, positive oral contrast is preferable over neutral contrast.

Today, neutral oral contrast agents that have attenuation similar to water (10–30 Hounsfield units [HU]) are routinely used for CT enterography.4 Their low attenuation combined with intravenous contrast administration allows excellent visualization of the bowel wall and its lumen by maximizing their attenuation differences. The low Hounsfield value of these agents also makes them ideal for CT angiography and positron emission tomography–CT.29–31

A variety of neutral contrasts are available, including water, whole milk, methylcellulose solution, polyethylene glycol solution, and low-density barium suspension with sorbitol (0.1% weight per volume barium sulfate suspension).4,5 Water is a useful contrast agent when used in the upper abdominal CT studies.6,32 However, it has a slow intestinal transit and is rapidly absorbed through the intestinal wall, resulting in unsatisfactory distension of the jejunal and ileal loops.4,6 Therefore, water has limited utility for the evaluation of Crohn disease, where the ileum is commonly involved, or of occult gastrointestinal hemorrhage, where the bleeding site may be anywhere in the small bowel.

Water resorption, however, can be slowed with some additives. Neutral oral contrast agents containing osmotic additives, such as polyethylene glycol or sugar alcohols (mannitol and sorbitol), improve small bowel distention significantly and result in superior visualization of its mural features.5,6,33,34 Megibow and colleagues6 demonstrated that the low-density barium suspension with sorbitol significantly improved bowel distention in all segments of the gastrointestinal tract when compared with water and methylcellulose solution (Fig. 2). Young and colleagues33 reported better tolerance of low-density barium suspension with sorbitol when compared with polyethylene glycol solution. Another study comparing low-density barium suspension and sorbitol with a solution containing 0.2% of locust bean gum and 2.5%
mannitol demonstrated that both oral agents resulted in better bowel distension than water, but no significant difference was observed between them. A comparison study between milk and low-density barium suspension with sorbitol by Koo and colleagues did not demonstrate significant difference in bowel distension. However, milk may not be well tolerated by many patients and is difficult to store, limiting its use.

There are slight variations in the dosage and timing of oral contrast agent for CT enterography. Kuehle and colleagues, comparing different volumes of the low-density barium suspension with sorbitol, demonstrated that the best bowel distension was achieved with 1350 mL and the result did not improve by increasing the volume to 1800 mL. Moreover, administration of 1800 mL of contrast agent led to lower patient acceptance and higher rate of side effects, such as mild diarrhea and abdominal cramps. In our center, we use 1350 mL of low-density barium suspension with sorbitol. Our protocol is summarized in Box 1. Fasting for 6 hours is required to reduce the possibility of misinterpreting ingested hyperdense debris as enhancing lesion or focus of hemorrhage.

Optimal distension of terminal ileum is observed at 45 to 60 minutes after the ingestion of oral contrast, reducing significantly after this period. However, the duodenum and proximal jejunum distend early (15–20 minutes after the ingestion), which may be a consideration in the evaluation of pathologic processes involving these segments. Patients should be instructed about the importance of continuous intake of the oral contrast and monitored by a nurse or technologist as they ingest the contrast. Noncontinuous intake or poor timing of oral contrast will almost certainly lead to a poor study. In patients who are debilitated and unable to drink large volumes of the neutral oral contrast, CT enteroclysis may be a better option.

Metoclopramide or glucagon has been used by some investigators to increase gastric and small bowel distension. However, their efficacy remains unproven and, thus, their use is not universal.

**Administration of Intravenous Contrast Material**

The use of intravenous contrast is mandatory in CT enterography. Without the use of intravenous contrast material, mural enhancement of the bowel cannot be assessed and intraluminal masses or gastrointestinal hemorrhage may not be visible. Optimal mural enhancement requires rapid intravenous administration of contrast, usually at a rate of 4 to 5 mL/s. Variables, such as cardiac output, weight, and rate of contrast administration, may affect peak enhancement. Therefore, bolus timing

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**Box 1**

**Enteric contrast material administration protocol for CT enterography**

- Nothing by mouth for 6 hours before scanning
- Oral administration of low-density barium suspension with sorbitol (total of 1350 mL over 60 minutes):
  - 450 mL during the first 20 minutes (60–40 minutes before scanning)
  - 450 mL during the second 20 minutes (40–20 minutes before scanning)
  - 225 mL during the third 20 minutes (20–0 minutes before scanning)
  - 225 mL on CT table
techniques may be beneficial in optimizing enteric enhancement.\textsuperscript{23,36} When there is a contraindication to iodinated intravenous contrast, CT with positive oral contrast or MR enterography is preferred.\textsuperscript{4,37}

CT enterography for the evaluation of inflammatory bowel disease is usually accomplished in a single phase.\textsuperscript{10} For the evaluation of suspected or confirmed small bowel tumors, a precontrast phase should be included to distinguish radiodense material in the gut from enhancing masses or contrast extravasation into the lumen.\textsuperscript{13}

At our institution, CT enterography for diagnosis or evaluation of inflammatory bowel disease is performed during the enteric phase (45 seconds after initiating intravenous contrast administration). During the enteric phase, mural enhancement is at its maximum and the conspicuity of small bowel mural features is accentuated (Fig. 3).\textsuperscript{4,9,38} Shindera and colleagues\textsuperscript{23} demonstrated that the peak of small bowel mural enhancement is about 14 seconds after the peak of aortic enhancement or approximately 50 seconds after the start of intravenous contrast administration (starting at 45 seconds and ending at 54 seconds). They also found that during the venous phase (70 seconds after intravenous contrast administration) the enteric enhancement was significantly lower than in enteric phase. Vandenbroucke and colleagues,\textsuperscript{39} however, demonstrated no significant difference in the performance of enteric or portal venous phases when assessing Crohn disease activity.

In the evaluation of mesenteric ischemia and small bowel bleeding or neoplasm, a multiphasic study is performed. Huprich and colleagues\textsuperscript{13} demonstrated the utility of tri-phasic study in

\begin{figure}[h]
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\caption{Effects of scan time on mural enhancement in a normal CT enterography. (A) Precontrast phase. (B) Enteric phase. (C) Portal venous phase. Note optimal mural enhancement during the enteric phase (B).}
\end{figure}
depicting the source of obscure gastrointestinal bleeding. They performed the first phase at the peak of aortic enhancement, the second at enteric phase (20–25 seconds after the beginning of the arterial phase acquisition) and the third at 70 to 75 seconds after the beginning of the arterial phase. In our institution, we perform a multiphasic study that includes an unenhanced phase, followed by arterial and portal venous phases. The unenhanced phase is used to detect radiodense debris that may mimic contrast extravasation. The arterial phase is essential for detection of vascular lesions. The portal venous phase obtained at 70 seconds is useful for the evaluation of neoplastic lesions as well as for contrast extravasation. Table 1 summarizes the image acquisition timing protocols for different applications of CT enterography in our institution.

**Image Acquisition and Display**

Scanning is preferably performed on MDCT scanners with 16 or more channels (submillimeter collimation) to improve spatial resolution and to avoid issues related to slow acquisition. To reduce motion artifact, the table speed is adjusted to complete the image acquisition within one breathhold. The images are acquired from the diaphragm to the pubic symphysis and reconstructed with a section thickness of 2 mm (1–3 mm) and reconstruction interval smaller than 2 mm. Dose modulation, when available, should be used to reduce radiation exposure. Table 2 outlines the acquisition parameters for CT enterography.

**INTERPRETATION**

Coronal and sagittal reformations are essential when interpreting a CT enterography study. Image reconstructions can be performed at the scanner console or may be obtained from the thin slices on an independent image-processing workstation. Multiplanar images allow better depiction and characterization of enteric and extraenteric abnormalities and are an excellent tool for problem solving. Box 2 summarizes the role of multiplanar reformations in interpretation of CT enterography.

**Crohn Disease**

Involvement of the bowel in Crohn disease is transmural, segmental, and usually discontinuous. The small bowel is involved in almost 80% of the cases, with ileocecal region affected in 50%. Clinical signs and symptoms vary widely depending on the segment affected and the degree of inflammatory response.

Routine CT with positive oral contrast agent is routinely used to evaluate extraenteric complications of Crohn disease. CT enterography has the added advantage of depicting mural and luminal abnormalities, thus differentiating acute from

<table>
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<th>Table 1: Timing of image acquisition for CT enterography</th>
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<td><strong>Indication</strong></td>
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<td>Inflammatory bowel disease</td>
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<td>Obscure gastrointestinal bleeding</td>
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chronic Crohn disease. This differentiation is critical because active disease is usually treated medically but chronic disease may require surgical intervention.

**Active Crohn disease**

CT enterography findings of active Crohn disease include mural hyperenhancement, mural stratification, bowel wall thickening, increased attenuation in the perienteric fat, and engorged vasa recta ("comb" sign). Mural hyperenhancement refers to segmental hyperenhancement of the small bowel wall when compared with the adjacent small bowel loops. The comparison should be made to the loops in the same region because normal jejunal loops enhance to a greater degree than normal ileal loops (Fig. 4). It is also important to compare the bowel loops with similar degree of distension because normal collapsed loops exhibit greater attenuation than distended ones do. When assessing nondistended bowel loops, secondary signs of Crohn disease, such as perienteric fat stranding, engorged vasa recta, fistula, and abscess formation, can be used for staging.

Mural hyperenhancement is the most sensitive CT finding of active Crohn disease (Fig. 5). The degree of bowel wall enhancement correlates with the severity of active inflammation and may be used to monitor anti-inflammatory therapy. Hara and colleagues observed that CT enterography findings positively correlated with disease progression or regression.

Quantitative measurement techniques have been used to objectively correlate mural hyperenhancement and wall thickness with disease activity. Using a mural attenuation threshold of 109 HU and an abnormal-to-normal loop enhancement ratio of more than 1.3, CT enterography is highly correlated with histologic findings of active disease. Visual assessment, however, presents higher specificity than do quantitative measurements.

Mural stratification is visualization of the bowel wall layers on CT after intravenous contrast administration. Edematous bowel wall usually has a trilaminar appearance on CT enterography ("target" sign): an internal ring of mucosal enhancement, an external ring of serosal and muscular enhancement, and an interposed submucosal layer with decreased attenuation (Fig. 6). In chronic inflammatory bowel disease, fat deposition may be seen in the submucosa and should not be

| Table 2: Acquisition parameters for CT enterography |
|---|---|
| **Parameter** | **Measure** |
| Area covered | Diaphragm to the pubic symphysis |
| Table speed | Scanning the covered area in one breath-hold |
| Kilovolts | 120 |
| Milliamperes | Dose modulator |
| Detector collimation | ≤ 1 mm (16- to 64-channel MDCT) |
| Slice thickness | 2 mm |
| Interval reconstruction | ≤ 2 mm |
| Reformatted images | Coronal: 2 × 2 mm; sagittal: 2 × 2 mm |
| Maximum intensity projection | Coronal recommended: 4 × 2 mm |
| Reconstruction algorithm | Medium-sharp reconstruction kernel |

**Box 2: Role of multiplanar reformations in interpreting CT enterography**

**Axial**
Usually best for evaluating closely apposed loops of the small bowel and interloop abscesses

**Coronal**
Allows a global view of the small bowel in its entirety
Helps identify the terminal ileum and quantify length of involved segments
May help identify and localize fistulas

**Sagittal**
Particularly helpful in evaluating the rectum and in detecting fistulas

**Coronal maximum intensity projections**
Helpful for visualizing perienteric mesenteric stranding and engorged vasa recta, and for evaluating vascular structures
confused with the mural stratification that is seen with acute disease (Fig. 7). In chronic Crohn disease, mural stratification may be absent because of the transmural fibrosis, leading to a homogeneous and less-intense enhancement. Mural stratification is not specific for Crohn disease and may be seen with other small bowel nonneoplastic etiologies, such as ischemia, ulcerative colitis, and radiation enteritis.

Mural thickening refers to wall thickness of greater than 3 mm in a distended bowel loop. It correlates highly with disease activity and, present in up to 82% of patients, it is the most frequently observed CT finding in Crohn disease. When associated with mural hyperenhancement, it is the most sensitive sign of active disease.

Increased attenuation of the mesenteric fat is due to edema and engorgement of the vasa recta. The prominence and engorgement of the vasa recta adjacent to the affected bowel loop is also known as the “comb” sign. Increased attenuation of the mesenteric fat in combination with the “comb” sign is the most specific CT finding for active Crohn disease (Fig. 8). Colombel and colleagues demonstrated that the perienteric findings of inflammation on CT enterography correlate with the levels of C reactive protein, a marker of disease activity. Lee and colleagues observed that when the “comb” sign is present, the patients were more likely to be admitted to the hospital and to receive aggressive treatment.

Chronic Crohn disease
The long-standing inflammatory process leads to chronic manifestations of Crohn disease. CT
Enterography signs of chronic disease are submucosal fat deposition, sacculations, fibrofatty proliferation, and strictures.\(^5\)

In Crohn disease, the mesenteric border of the bowel is preferentially affected by the inflammatory process. This may result in eventual mural fibrosis and shortening of the wall. Asymmetric fibrosis, combined with the constant increase in intraluminal pressure during the peristaltic movements, results in sacculations of the antimesenteric wall (Fig. 9).\(^3\)

Fibrofatty proliferation has been long recognized as a hallmark of Crohn disease. It extends from the mesenteric attachment and partially covers the chronically inflamed loop of bowel, classically the terminal ileum. Recent studies suggest that the hypertrophied mesenteric fat might have a role—related to the fat’s capacity to produce tumor necrosis factor \(\alpha\)—in sustaining the inflammatory process in Crohn disease.\(^52\)

Strictures that may occur in patients with active disease are due to inflammatory process and bowel spasm. However, strictures are more frequent with chronic fibrosis.\(^43,47\) CT enterography, similar to SBFT and enteroclysis, has a high sensitivity for diagnosing strictures. A stricture due to acute disease, manifested by bowel wall hyperenhancement, thickening, and mural stratification, is usually treated medically. Lack of enhancement and loss of stratification suggests transmural fibrosis and may require surgical intervention.\(^47\) The findings of acute and chronic Crohn disease are summarized in Box 3.

Wireless capsule endoscopy is contraindicated when strictures with a luminal diameter of less than 1 cm are present (Fig. 10).\(^17,53\) CT enterography, therefore, assumes an important primary role in the identification of the small bowel strictures.\(^5,16\) Voderholzer and colleagues\(^53\) in a prospective comparison of wireless capsule endoscopy and CT enteroclysis, could not evaluate 27% of their patients with wireless capsule endoscopy because of strictures identified on CT enteroclysis. However, wireless capsule endoscopy has high sensitivity when mild mucosal abnormalities are present and may be useful in the assessment of Crohn disease when both ileocolonoscopy and CT enterography are normal.\(^53\) Fig. 11 shows the algorithm illustrating our approach to the assessment for Crohn disease.

![Fig. 6. Mural stratification (arrowheads) indicative of active inflammation. CT enterography also shows deep ulcer (arrow) extending to the serosal surface.](image)

![Fig. 7. Coronal (A) and sagittal (B) CT enterography images demonstrate mucosal thickening and hyperenhancement as well as submucosal edema indicative of active disease (arrows). Submucosal fat deposition due to chronic disease is present concurrently (arrowheads).](image)
CT has an established role in the evaluation of extraenteric complications of Crohn disease. The most common extraenteric complications include fistula, sinus tract, abscess (Fig. 12), and flegmon.\(^2,45,47,54\)

CT enterography has a high sensitivity for diagnosing fistulae. A recent study demonstrated that CT enterography correctly identifies the presence or absence of fistulae in 94% of patients.\(^47\)

Multiplanar reformations are particularly useful for detecting fistulae. CT enterography can detect clinically unsuspected fistulae, resulting in changes in treatment regimen.\(^55\)

Other extraenteric manifestations of Crohn disease, such as mesenteric lymphadenopathy, cholelithiasis, nephrolithiasis, sacroiliitis, and primary sclerosing cholangitis, can also be evaluated.\(^5\)

**Gastrointestinal Bleeding**

Gastrointestinal bleeding may be overt or occult. Overt hemorrhage can be due to active bleeding and may be detected by CT enterography. Yoon and colleagues\(^56\) detected 20 of 22 angiographically confirmed sites of active hemorrhage by CT during the arterial phase. Jaeckle and colleagues\(^57\) reported similar results in a recent study.

The American Gastroenterological Association defines obscure gastrointestinal bleeding as persistent or recurring bleeding of unknown origin after negative upper and lower endoscopies.\(^58\) Following the initial negative studies, a second evaluation with upper and lower endoscopy is performed to identify a possible overlooked lesion. The attention is turned to the small bowel if the second-look examinations are also negative.\(^58\)

The source of obscure gastrointestinal bleeding is the small bowel in approximately 5% to 10% of patients.\(^58\) Various imaging modalities are used for diagnosis, including wireless capsule...
endoscopy, push enteroscopy, double-balloon endoscopy, CT enterography, nuclear scan, and SBFT. Currently, wireless capsule endoscopy is the most sensitive examination for detecting the source of occult bleeding with reported sensitivity ranging from 42% to 80%.60–62 In a meta-analysis by Treister and colleagues63,64 wireless capsule endoscopy was superior to push enteroscopy and small bowel radiography for detecting small bowel pathology. However, as previously discussed, wireless capsule endoscopy has several disadvantages that may limit its use. SBFT has a limited role in the detection of obscure gastrointestinal bleeding. Its main role is to exclude adhesions and strictures in planning for capsule endoscopy.

The role of CT enterography in the workup of obscure gastrointestinal bleeding is still evolving. CT enterography is an excellent adjunct in the workup of obscure gastrointestinal bleeding. A distinct advantage of CT enterography over wireless capsule endoscopy is its ability to evaluate submucosal and serosal abnormalities.13 Tew and colleagues65 reported that MDCT correctly showed the site of bleeding in 7 of 10 patients. Huprich and colleagues13 reported that multiphasic CT enterography demonstrated the site of bleeding in 8 of 10 patients. Additionally CT enterography was able to depict abnormalities not identified by wireless capsule endoscopy and colonoscopy.13

CT enterography protocols for the evaluation of obscure gastrointestinal bleeding are optimized to detect an abnormal area of enhancement in bowel wall or to demonstrate active bleeding.13 As described previously, multiple phases are necessary for the detection of gastrointestinal bleeding. Our protocol is summarized in Table 1.

The differential diagnosis for obscure gastrointestinal bleeding can be narrowed based on the age of the patient. In the geriatric population, vascular lesions and nonsteroidal anti-inflammatory drug (NSAID) enteropathy are the most common causes of small bowel bleeding.59 Vascular lesions consist of a variety of different entities with different angiographic and CT appearances.59,66 Angiodysplasia is the most frequent vascular lesion of the bowel. An early filling vein during the arterial phase may be a clue to the nearby location of this lesion.66,67 Active small

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**Box 3**

**Findings of active and chronic Crohn disease on CT enterography**

**Findings of active inflammation**
- Mural hyperenhancement, stratification, and thickening
- Perienteric fat stranding and engorged vasa recta

**Findings of chronic inflammation**
- Submucosal fat deposition
- Mural thickening without enhancement
- Perienteric fat hypertrophy
- Sacculation of antimesenteric bowel wall

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**Fig. 10.** Axial CT enterography image shows retained capsule endoscope (arrow) with an adjacent enterolith (arrowhead) in a dilated ileal loop proximal to a stricture (not shown).

**Fig. 11.** Algorithm showing authors’ approach to the assessment for Crohn disease.
bowel bleeding is observed as gradual accumulation of contrast material within the bowel lumen on multiphasic CT enterography (Fig. 13).\textsuperscript{13} NSAID erosions and ulcers are difficult to distinguish from Crohn disease on wireless capsule endoscopy.\textsuperscript{68} NSAID-related weblike strictures in the small bowl are a cause for retained wireless capsule.

In younger adults, Crohn disease, tumors, and Meckel diverticulum are the most frequent sources of occult gastrointestinal bleeding.\textsuperscript{59,69}

**Small Bowel Neoplasms**

Small bowel tumors are uncommon and represent 3\% to 6\% of all gastrointestinal tumors. The clinical symptoms are frequently nonspecific, resulting in delayed diagnosis.\textsuperscript{70} The most common tumors are gastrointestinal stromal tumors (Fig. 14), adenocarcinoma, lymphoma, and carcinoid tumors.\textsuperscript{71,72} CT enterography may be helpful in detection of polyps in polyposis syndromes. Multiphasic CT enterography, with similar protocol as described for gastrointestinal bleeding, is required to detect many of these neoplasms.\textsuperscript{70} Although some tumors are better visualized on the arterial phase, others may be more conspicuous on the portal venous phase (see Fig. 14).

Although there are no large published studies on the efficacy of CT enterography for evaluating small bowel tumors, Pilleul and colleagues\textsuperscript{70} reported an accuracy of 84.7\% in depicting small bowel neoplasms with CT enteroclysis.

**Fig. 12.** Presacral abscess (arrows) in a patient with Crohn disease. Sagittal reformations are very useful for the evaluation of the presacral space.

**Fig. 13.** Axial (A) and sagittal (B) images of active bleeding in the right colon (arrows) due to angiodysplasia.
SUMMARY

CT enterography is a new imaging modality that has several advantages over conventional CT, wireless capsule endoscopy, and barium examination. CT enterography is noninvasive and allows mapping of disease activity before endoscopy and in cases where the endoscope cannot reach a bowel segment. It is rapid, readily available, operator independent, and allows evaluation of extraenteric complications of small bowel disease. Its role as the first-line modality in the work-up of suspected or known small bowel pathology is evolving.

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