Crohn disease is a complex pathologic process with an unpredictable lifelong course that includes frequent relapses. It often affects young patients, who are most vulnerable to the potential adverse effects of repeated exposure to ionizing radiation from computed tomography performed for diagnosis and surgical planning. The small intestine is the bowel segment that is most frequently affected, but it is the least accessible with endoscopic techniques. Magnetic resonance (MR) enterography has the potential to safely and noninvasively meet the imaging needs of patients with Crohn disease without exposing them to ionizing radiation. Appropriate use of MR enterography requires a carefully crafted protocol to depict signs of active inflammation as well as complications such as bowel obstruction, fistulas, and abscesses. Interpretation of MR enterographic images requires familiarity with the imaging signs and mimics of active bowel inflammation and stenosis. Although MR enterography currently is helpful for management in individual patients, the standardization of acquisition protocols and interpretive methods would increase its usefulness for more rigorous, systematic assessments of Crohn disease treatment regimens.

Abbreviations: CDAI = Crohn disease activity index, SSFP = steady-state free precession, 3D = three-dimensional

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**Introduction**

Crohn disease is an idiopathic chronic inflammatory disease of the gastrointestinal tract that has varying levels of severity, diverse manifestations, and an unpredictable course. Crohn disease has a prevalence of around 100–200 per 100,000 people in North America and Europe, with approximately 400,000–600,000 people affected in North America (1). The etiology of Crohn disease is complex and likely multifactorial, with genetic, immunologic, infectious, microvascular, and possibly environmental and lifestyle factors contributing (2,3). Enteric involvement tends to be segmental, and inflammation often is transmural. Superficial mucosal (aphthous) and deep linear ulcers may be present, separated by segments of uninvolved mucosa (“skip lesions”) (Fig 1), depending on the severity and chronicity of Crohn disease. Coalescent longitudinal and transverse ulcers yield a “cobblestone” appearance of the bowel mucosa, a finding seen in more advanced cases of Crohn disease (4). Histologic hallmarks of Crohn disease include expansion of the lamina propria with chronic inflammatory cells, crypt architectural distortion, cryptitis, crypt abscesses, ulcers, noncaseating granulomas, transmural lymphoid aggregates, thickening of the muscularis mucosae, and submucosal fibrosis (Fig 2) (4).

Crohn disease is chronic, has a peak age of onset in the 2nd–4th decades of life, and follows an unpredictable course with periodic recurrences and exacerbations (1). Patients frequently are subjected to multiple imaging examinations in which they are exposed to ionizing radiation, often beginning in adolescence or early adulthood. The small bowel is the most common site of Crohn disease and the least accessible with endoscopy. Often, the disease involves the terminal ileum by the time it is diagnosed. Although upper gastrointestinal involvement is rare, Crohn disease may affect any segment, or multiple noncontiguous segments, of the small bowel. Over time, in many patients, penetrating or stricturing disease develops that sometimes requires surgical intervention (5). Common complications of small-bowel Crohn disease include bowel obstructions, fistulas, and abscesses.

Clinicians often use medical history, laboratory data, and physical examination to assess disease activity and complications, but these tools are relatively nonspecific. Clinical observations of disease activity are subjective and prone to significant interobserver variability (6). Because the symptoms of active inflammation and those of complications may be indistinguishable, imaging often is needed.

These challenges highlight the need for a cross-sectional imaging technique that is sensitive enough to allow detection of bowel inflammation and its complications and that allows differentiation between acute disease that can be managed medically and disease that requires surgery. In addition, the ideal imaging test would be reproducible, well tolerated by patients, and free of ionizing radiation.

In this article, we explain how to perform MR enterography in patients with Crohn disease and how to interpret MR enterographic images, and we describe the expanding role of MR enterography in the clinical management of Crohn disease.

**Why Use MR Imaging to Assess Small-Bowel Involvement in Crohn Disease?**

Imaging of patients with Crohn disease traditionally has included a combination of fluoroscopic and computed tomographic (CT) techniques to assess the small bowel. The former method consists of small-bowel follow-through examinations...
and enteroclysis, which provide views of the bowel lumen and mucosal surface but only limited, indirect information about extraenteric complications. CT provides detailed information about the bowel wall and extraenteric structures at the expense of mucosal detail. Recognizing the complementary nature of these techniques, investigators have sought to combine the best of both in CT enteroclysis and CT enterography (7,8). Despite the diagnostic success attained with these CT techniques, their use is limited because of their dependence on ionizing radiation, a significant liability given the need for repetitive imaging in a subset of young patients with Crohn disease (9).

Reported radiation doses for multidetector CT of the abdomen and pelvis vary widely, ranging from 6 to 28 mSv (10–12). For example, Jaffe et al (9) reported an effective dose of 16.1 mSv for abdominal and pelvic multidetector CT. The hazards of radiation exposure, particularly in the young, are well known, although the details are controversial. Standard radiation doses for multidetector CT are within accepted limits; 50 mSv is the yearly limit for radiation workers in the United States. However, some estimates suggest that an effective dose of 10 mSv may correspond to an estimated excess risk of 1 in 2000 for developing fatal cancer (13). This alone should spur interest in the use of magnetic resonance (MR) imaging for the evaluation of younger patients with Crohn disease.

Without the risks of ionizing radiation, MR imaging provides superior soft-tissue contrast and excellent depiction of fluid and edema. Enhancement with gadolinium-based contrast material increases the ability to detect subtle inflammation. Unlike CT, steady-state free precession (SSFP) MR imaging sequences can depict bowel motility, a potential advantage when attempting to distinguish between fixed and transient segments of narrowing. Sequences may be repeated to capture multiple discrete vascular phases, reassess abnormal bowel segments, or improve image quality without increasing the radiation risk to the patient.

MR imaging is more reliable than fluoroscopic enteroclysis for correctly identifying areas of Crohn disease involvement, except perhaps for mucosal abnormalities (14,15). The relative merits of CT and MR enterography, apart from the issue of radiation exposure, are less clear; in particular, there is uncertainty as to which method better depicts wall thickening and enhancement (16,17).
Horsthus et al (18) conducted a meta-analysis and reported that there was no statistically significant difference between MR imaging and CT in the ability to depict inflammatory bowel disease, including extraenteric complications, on a per-patient basis across multiple studies.

Video capsule endoscopy may be used to evaluate disease activity in the small bowel of patients with Crohn disease or to determine if Crohn disease is present in the small bowel of patients under consideration for surgical therapy for colitis. Comparisons between video capsule endoscopy and MR imaging for assessment of small-bowel Crohn disease have shown these techniques to be complementary, with video capsule endoscopy better depicting mucosal disease and MR imaging showing additional transmural and extramural findings (19,20). Aside from its inability to depict the bowel wall and extraluminal findings, video capsule endoscopy may be limited by bowel strictures and obstructions (21). In a recent study by Solem et al (22) of 41 patients studied with a variety of imaging techniques in addition to video capsule endoscopy, 17% had an asymptomatic partial small-bowel obstruction, although none of the obstructions caused capsule retention.

**MR Enterography versus MR Enteroclysis**

The benefits of using enteric contrast material to achieve bowel distention for cross-sectional imaging are not disputed, although the optimal type of contrast material and method of administration remain somewhat controversial. For the purposes of this article, when enteric contrast material is administered through an enteric tube we use the term enteroclysis, and when it is administered orally we use the term enterography. Current data suggest that although bowel distention achieved with the enteric intubation technique generally is superior to that achieved with enterography, the improved distention does not necessarily translate into a clinically significant improvement in diagnostic effectiveness (23,24).

A recent study by Masselli et al (15) confirmed the benefit of enteric intubation for bowel distention but reported equivalent diagnostic performances with the enteric and oral techniques in identifying stenoses and fistulas. However, MR enteroclysis was superior to MR enterography in demonstrating mucosal abnormalities (15). The importance of detecting mucosal disease in patients without bowel obstruction has diminished in the era of capsule endoscopy. Patient acceptance, which favors MR enterography over MR enteroclysis, also must be considered, because many patients need multiple examinations (25).

**MR Enterography Technique**

**Patient Preparation**

Techniques for performing MR enterography vary among institutions, but it is generally agreed that administering an enteric contrast agent is essential to achieve some degree of bowel distention. Instructing patients to fast for approximately 6 hours before the procedure improves compliance with and tolerance for ingestion of oral contrast material; nevertheless, to our knowledge, the benefits and lengths of fasting have not been rigorously studied. Some investigators have advocated concomitant instillation of rectal contrast material before imaging to allow simultaneous assessment of the small bowel and colon (26,27). In addition to improving colon distention, instillation of a rectal enema may improve distention of the terminal ileum (26,27). Because the colon is readily accessible at colonoscopy, we do not routinely perform rectal enemas.

Halting peristalsis reduces blurring and artifacts related to bowel motility. We have found that, for adults, administering 1 mg of glucagon intramuscularly after cine imaging and before contrast-enhanced T1-weighted and fat-suppressed T2-weighted MR imaging serves this purpose well. Contraindications to the use of glucagon include known hypersensitivity to the commercial preparation and known or suspected pheochromocytoma or insulinoma.

**Administration of Oral Contrast Material**

With regard to oral contrast material administration for MR enterography, three issues must be addressed: (a) the composition of the contrast material, (b) the volume to be administered, and (c) the timing of image acquisition after ingestion of contrast material. A commercial preparation of 0.1% (wt/vol) barium suspension containing sorbitol is effective, well tolerated, and convenient for MR enterography (28,29). Use of this agent produces high signal intensity in the bowel lumen on T2-weighted images and low signal intensity in the lumen on T1-weighted images. The dark lumen is critical for the detection of mural enhancement on postcontrast T1-weighted images, but water alone does not provide adequate bowel distention for MR enterography.
In the literature, reported volumes of oral contrast material vary considerably, but most studies report a total volume of 1–2 L. Ingested volumes of mannitol or sorbitol solution at the higher end of this range may result in more side effects, such as diarrhea, excess intestinal gas, and abdominal cramps, although side effects also may be reduced by keeping the sugar alcohol concentration below 2.5% (30,31). We administer portions of the commercial oral contrast preparation alternately with plain water to improve patient tolerance, although this method is optional. We attempt to achieve a minimum ingested volume of 1 L, although some symptomatic patients may be unable to comply. To allow distal transit, we employ a minimum delay of 45 minutes from the start of contrast ingestion to imaging (28,30,32). The additional administration of intravenous erythromycin and prone imaging have been recommended to improve gastric emptying and bowel loop separation, respectively, but we do not implement these strategies in our practice (15,30,32).

Sequences and Protocol
MR enterography imaging protocols vary because of differences in available equipment and personal preferences. We use a 1.5-T MR imaging system with a 12-channel torso receiver coil that is capable of parallel imaging and that allows coronal acquisitions to encompass the entire small bowel in a single field of view. Despite differences in MR imaging equipment and software, certain basic elements are common to most imaging protocols for Crohn disease. We begin an MR enterography examination with coronal T2-weighted single-shot fast spin-echo or coronal half-Fourier acquisition single-shot turbo spin-echo imaging of the abdomen and pelvis. These initial sequences are primarily applied for localization and anatomic overview, although areas of bowel wall thickening, edema, and luminal dilatation often are visible (Fig 3a).

Next, we apply a multiphase multisection coronal SSFP MR sequence that covers the entire small bowel and colon. We generally acquire 15–25 phases per section location during free breathing. These images may then be displayed as a cine loop to assess bowel motility, exclude or confirm fixed stenoses and segmental dilatation, and detect adhesions (33–35). Because of the high image contrast, this type of sequence is helpful for assessing mesenteric vascularity and lymphadenopathy (Fig 3b).
After glucagon is administered, we acquire coronal fat-suppressed three-dimensional (3D) T1-weighted breath-hold gradient-echo images of the abdomen and pelvis before and after intravenous gadolinium-based contrast material is administered. We typically acquire an arterial phase image 25 seconds after contrast material administration, followed by two additional coronal acquisitions, allowing the patient to breathe for a brief period between each acquisition. Although the value of rapid dynamic imaging in the assessment of bowel wall enhancement in patients with Crohn disease has been questioned, we have found that when several complete volumetric data sets are acquired within 2 minutes after contrast material administration, at least one data set generally is motion free and includes the period of peak bowel wall enhancement, which can vary between patients (36,37). These coronal contrast-enhanced images allow assessment of the vasculature, lymph nodes, and bowel wall enhancement (Fig 4). Enteric fistulas and abscesses also are depicted. We frequently include a set of delayed contrast-enhanced axial images for multiplanar correlation (Fig 5).

Immediately after the coronal contrast-enhanced acquisitions, we obtain a set of axial fat-suppressed T2-weighted images to assess the bowel wall and surrounding tissues for fluid and edema (Fig 6) (38,39). We also routinely obtain a set of coronal diffusion-weighted images \( b = 800 \text{ sec/mm}^2 \), although the utility of diffusion-weighted imaging in the MR imaging assessment of Crohn disease remains an area of investigation. It is hoped that diffusion-weighted images will help identify areas of active inflammation, fistulas, and abscess formation (Fig 7).

**Interpretation of MR Enterographic Images**

**Spectrum of Findings of Small-Bowel Crohn Disease**

Crohn disease may be classified as active inflammatory (without fistulas or stenoses), penetrating, or fibrostenotic disease, depending on the imaging features (40,41). Patients may exhibit characteristics of more than one disease subtype.
Figure 6. Mural edema and inflammatory fluid in a patient with Crohn disease. Axial fat-suppressed T2-weighted MR image shows high-signal-intensity bowel wall (arrow) and fluid surrounding the distal ileum (arrowhead).

Figure 7. (a) Coronal diffusion-weighted image ($b = 800$ sec/mm$^2$) obtained in a young man with Crohn disease shows two focal areas of increased signal intensity (arrows). (b) Coronal contrast-enhanced fat-suppressed T1-weighted 3D gradient-echo MR image obtained at the same level as a shows that the high-signal-intensity areas correspond to extraluminal fluid collections (arrows), which were initially thought to represent small-bowel loops at CT and MR imaging. An abscess was diagnosed, but an attempt at percutaneous drainage was aborted because of difficulty in distinguishing the abscess from adjacent bowel. The diagnosis was confirmed at surgery.

and it is common for a single resected bowel specimen to contain areas of acute inflammation, chronic inflammation, and fibrosis (Fig 2). The role of radiologists is to describe the features of each subtype that are seen at imaging. Correlation with clinical data helps determine the significance of the findings.

Active Inflammation.—At pathologic analysis, active inflammation is characterized by varying degrees of neutrophilic crypt injury. In mildly active Crohn disease, a small fraction of crypts are infiltrated by neutrophils (cryptitis), with
Figure 8. Stratified enhancement of bowel in a 53-year-old man with active Crohn disease. Coronal contrast-enhanced fat-suppressed T1-weighted 3D gradient-echo MR image shows stratified mural enhancement in a small-bowel loop (arrow). The hyperenhancing inflamed mucosa at the center is surrounded by a lower-signal-intensity ring of submucosal edema and an outer ring of enhancing serosa, creating a targetlike appearance at cross-sectional imaging.

Figure 9. Increased mesenteric vascularity (comb sign) due to acute inflammation in a 28-year-old man with active Crohn disease. Coronal contrast-enhanced fat-suppressed T1-weighted 3D gradient-echo image shows increased vascularity (arrow) adjacent to a hyperenhancing thickened segment of ileum (arrowhead). This patient’s condition improved with medical management.

Associated crypt destruction and mucin depletion. As the degree of activity increases, there is a corresponding increase in the proportion of involved crypts and the severity of crypt injury, including crypt epithelial necrosis, intraluminal exudate (crypt abscess), and eventual ulcer formation.

Two types of ulcers are seen in Crohn disease: superficial aphthous ulcers and deep fissuring ulcers. Deep fissuring ulcers are more problematic than superficial aphthous ulcers; they break through the mucosa and into the deeper layers of the bowel wall, initially resulting in submucosal inflammation and edema. At MR enterography, submucosal edema in the small bowel appears as wall thickening and produces increased signal intensity on T2-weighted images (Fig 6) (38,39,42). Mucosal and serosal enhancement, combined with intervening submucosal edema, contribute to a stratified or layered appearance on contrast-enhanced T1-weighted fat-suppressed images (Fig 8) (43,44).

Some investigators have reported that deep ulcers may be seen at MR enterography, whereas superficial ulcers defy detection (45). Increased mesenteric vascularity adjacent to the inflamed bowel loop (the comb sign) often is present in the setting of acute inflammation and is best identified on contrast-enhanced T1-weighted fat-suppressed images or SSFP images (Fig 9) (44). These sequences also clearly demonstrate reactive mesenteric lymphadenopathy, a finding frequently seen in patients with active Crohn disease (Fig 4). Some investigators have
identified lymph node enhancement as a finding that allows differentiation between active inflammatory and fibrostenosing disease, but the added value of this potential finding is unclear at present (46).

Typically, active inflammatory disease without fibrostenosing or penetrating complications is managed medically. The optimal medical management of Crohn disease is somewhat controversial, and first-line medical treatment regimens vary by practitioner and institution. Mesalamine, steroids, immunomodulators, and biologics (drugs that specifically target components of the immune system) are all used to varying degrees for the management of uncomplicated active Crohn disease.

**Penetrating Disease.**—Deep ulcer formation may lead to transmural inflammation and sinus tract formation, which may progress to fistulation. Fistulas may bridge adjacent loops of small bowel or cross from small bowel to the colon, stomach, bladder, or skin (Figs 5, 10). Penetrating disease

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**Figure 10.** Enterovesical fistula in a 49-year-old woman with Crohn disease and no history of recent bladder catheterization. (a) Axial fat-suppressed T2-weighted MR image shows an air bubble (arrow) in the bladder. (b) Coronal SSFP MR image shows tethering of the right bladder dome and an adjacent cluster of bowel loops (arrow) interconnected by fistulas and adhesions. (c) Coronal contrast-enhanced fat-suppressed T1-weighted 3D gradient-echo MR image shows a fistula between an ileal loop and the bladder (arrow). These findings were confirmed at surgery and pathologic analysis. The patient’s condition improved after surgery.
may cause the formation of abscesses, which often can be managed percutaneously (Figs 7, 11). The presence of penetrating disease in the absence of an abscess often alters medical therapy; clinicians generally avoid the use of steroids in such cases and may consider antibiotic or biologic therapy.

Fistulas, sinus tracts, and abscesses are visible on contrast-enhanced T1-weighted fat-suppressed MR images because of their avidly enhancing walls (47). In our experience, adhesions between adjacent bowel loops can be distinguished from fistulas because adhesions are fibrotic and tend to be thinner and enhance later than fistulas, whereas fistulas are composed of more vascular inflammatory tissue (Fig 12). Enteroenteric fistulas often form a complex network between closely adherent small-bowel loops that may appear as a stellate configuration on contrast-enhanced MR images (Fig 13).

**Fibrostenosing Disease.**—Over time, chronic inflammation within the bowel wall progresses to mural fibrosis. When fibrosis is associated with stricture formation, bowel obstruction may develop. It is important to identify fibrotic strictures with certainty because they are unresponsive to medical therapy. Fibrotic strictures resulting in symptomatic bowel obstruction typically require surgical resection.

On cine images, fibrotic strictures appear as aperistaltic bowel segments that often demonstrate fixed mural thickening and luminal narrowing (Fig 14). The thickened submucosa of a strictured, fibrotic bowel segment does not typically display increased signal intensity on T2-weighted images in the absence of active disease because of the lack of mural inflammation and edema. The presence
Figure 14. Fibrostenosing disease in a 28-year-old woman with long-standing Crohn disease. (a) Coronal SSFP image shows two jejunal strictures (arrows) that appeared stationary at cine imaging. No increased vascularity or lymphadenopathy is present in the adjacent mesentery. (b) Image obtained during a small-bowel barium study several years earlier shows the same strictures (arrows), providing evidence of their chronicity.

Additional Findings
We primarily perform MR enterography to assess the small bowel in patients with Crohn disease. However, active Crohn colitis may be incidentally discovered at MR imaging even in the absence of a prepared colon or when an enema has not been administered (Fig 16). In such cases, the colon demonstrates hyperenhancement, mural thickening, and mesenteric vascular engorgement. The role of diffusion-weighted imaging in the assessment of Crohn disease activity has not been established, but we have seen several cases of active Crohn colitis in which conspicuity of the inflamed colon was increased on diffusion-weighted images (Fig 16c).

of a fibrotic stricture does not exclude the possibility of coexistent active inflammation elsewhere in the bowel. Bowel dilatation proximal to a fixed, narrowed segment implies obstruction. Fecalization of the small-bowel contents may be visible at MR imaging and CT but is not highly specific to small-bowel obstruction (Fig 15) (48).
In patients with Crohn disease, not all small-bowel obstructions are the result of fibrotic strictures, and not all dilated small-bowel segments are obstructed. Peritoneal adhesions are common in Crohn disease and may lead to obstruction. In such cases, radiologists should look for acutely angled or tethered bowel loops, an abrupt transition in luminal diameter, and an absence of mural thickening. A short-segment stricture also may be associated with an abrupt transition in caliber, although it is typically seen in the absence of bowel tethering (Fig 18). Lack of a clearly
Figure 17. Submucosal edema associated with obstruction due to Crohn disease in a 37-year-old man. (a) Coronal single-shot fast spin-echo image shows an obstructing stricture of the terminal ileum (arrow) and a segment of more proximal small bowel with a high-signal-intensity submucosa (arrowhead). (b) Coronal contrast-enhanced fat-suppressed T1-weighted 3D gradient-echo image shows enhancement of the strictured segment and an enteroenteric fistula (arrow). The proximal small-bowel loop has a low-signal-intensity submucosa and thin mucosal and serosal layers (arrowhead). These findings are indicative of obstruction without inflammation, which was confirmed at surgery.

Figure 18. Weblike stricture in a 35-year-old man with a history of Crohn disease and abdominal pain. (a) Coronal single-shot fast spin-echo image shows an abrupt change in small-bowel caliber in the right lower quadrant (arrow). Contrast-enhanced images showed no evidence of active inflammation. (b) Endoscopic image obtained during double-balloon enteroscopy shows one of several short-segment strictures that were found (arrow). The strictures recurred after balloon dilatation and required surgical resection.
defined transition point in dilated small bowel is a finding typical of a functional abnormality in the absence of obstruction. It is important to distinguish functional bowel abnormalities from anatomic obstruction because patients with functional bowel abnormalities may not benefit from surgical intervention (Fig 19).

Collapsed bowel segments may appear thickened, with an avidly enhancing appearance that mimics that of active inflammation (Fig 20). Cine
SSFP imaging may be helpful in demonstrating the transient nature of bowel collapse. Secondary signs of acute inflammation, such as increased mesenteric vascularity, are absent in the setting of collapsed but otherwise normal bowel. Transient intussusception of jejunum also may mimic chronic small-bowel Crohn disease (Fig 21).

Not all patients referred for MR enterography for presumed or possible Crohn disease have the disease (Fig 22). Furthermore, processes other than Crohn disease may produce segmental bowel features very similar to those typical of Crohn disease (Fig 23). In particular, a targetlike enhancement pattern of the small bowel may be seen in radiation-induced or infectious enteritis, vasculitis, and intestinal ischemia.

**Figure 21.** Transient intussusception in a symptomatic 45-year-old man with a history of Crohn disease. (a) Coronal SSFP image shows a thickened jejunal loop (arrow). (b) Image from the same study as a (obtained at a more anterior level) shows intussusception of the jejunum (arrow), which resolved on later images. Multiple strictures seen elsewhere in the study were surgically treated.

**Figure 22.** Meckel diverticulum in a 28-year-old woman with CT findings that were initially interpreted as obstruction due to active Crohn disease after a history of suspected Crohn disease was provided. Coronal SSFP image from MR enterography shows multiple dilated small-bowel loops and a blind-ending structure in the mid abdomen (arrow). The blind-ending loop did not exhibit normal peristalsis at cine imaging. At surgery, adhesions related to a Meckel diverticulum were found to be obstructing the bowel. There was no evidence of Crohn disease.
Figure 23. Segmental small-bowel ischemia mimicking Crohn disease in a 63-year-old man with abdominal pain. Coronal contrast-enhanced fat-suppressed T1-weighted 3D gradient-echo image shows an avidly enhancing small-bowel segment (arrow) with the comb sign. Enlarged mesenteric lymph nodes were seen on other images. At surgery, the diseased segment was found to be ischemic, and metastatic carcinoid tumor was discovered in the mesenteric lymph nodes. The tumor is presumed to have obstructed the venous drainage of the affected loop, inducing ischemia.

Figure 24. Process diagram shows the proposed algorithm for the use of MR enterography (MRE) in managing Crohn disease (CD). A.I. = active inflammation; SBO = small-bowel obstruction; TI = terminal ileum.

Potential Impact of MR Enterography on Patient Treatment and Clinical Trials

MR enterography has the potential to impact three aspects of patient care: diagnosis, management, and clinical trials. Practices vary for management of Crohn disease; our algorithm should be considered only one possible approach (Fig 24).

Whereas MR enterography may be incorporated into the diagnostic evaluation of a new patient presenting with symptoms of Crohn disease, in most cases this is unnecessary. For many patients, the diagnosis is readily made at colonoscopy with terminal ileoscopy. However, patients who present with symptoms consistent with Crohn disease and who have normal findings at ileocolonoscopy may benefit from MR enterography to determine if there is enteric inflammation proximal to the terminal ileum. Also, MR enterography may be useful in identifying patients with terminal ileitis when intubation of the terminal ileum during colonoscopy is unsuccessful. Whether MR enterography is preferable to capsule endoscopy for the assessment of new patients with small-bowel Crohn disease is unclear at present, except perhaps in the setting of suspected bowel obstruction.
We have found MR enterography particularly useful for the detection of active inflammation and complications in symptomatic patients with known Crohn disease. MR enterography also may be helpful when symptoms are considered atypical for Crohn disease. In such cases, a finding of active bowel inflammation may prompt more aggressive medical intervention, whereas an absence of active disease or related complications may prompt an investigation of other possible causes to explain the patient’s symptoms.

MR enterography also may be used to monitor disease activity or to assess the effectiveness of interventions (Fig 25). Clinicians treating patients with Crohn disease are faced with a daunting task. Patients with Crohn disease often present with nonspecific symptoms, and clinical assessment of disease activity is a subjective process prone to significant interobserver variability (6). Clinical activity of Crohn disease may be quantified by using scoring systems such as the Crohn disease activity index (CDAI) or the Harvey-Bradshaw index (49,50). Although rarely used in clinical practice, the CDAI is the mostly widely used scoring system. It consists of a score between 0 and 600 that is based on both objective and subjective data collected over 7 days. A score of less than 150 suggests disease remission, and a score of 220–450 suggests moderate to severe activity.
The variables used to determine the CDAI score include the number of liquid bowel movements, abdominal pain, general well-being, the presence of extraintestinal manifestations, the use of antidiarrheal medication, the presence of an abdominal mass, hematocrit levels, and body weight. Because such activity indexes are cumbersome to determine, they are rarely used in routine clinical practice. Furthermore, it is clear that the CDAI is imperfect. For example, there are patients who do not have active Crohn inflammation but have high scores, and there are patients with active disease and low scores. There is clearly a need for a more objective noninvasive measure of disease activity that can be repeatedly and reproducibly performed even in young patients. Further investigation is needed to determine the reproducibility of MR enterography, and a set of standardized criteria for image interpretation needs to be established and rigorously tested before MR enterography can be adopted as such a measure.

It is impractical for patients enrolled in clinical trials to undergo colonoscopy before and after intervention. Often, clinical trials attempt to use biologic markers of Crohn disease inflammation, such as the C-reactive protein level in serum or fecal calprotectin. These noninvasive biologic markers have substantial limitations as indicators of the response to medical therapy. MR enterography holds great promise for assessing response to therapy in Crohn disease trials. The lack of radiation exposure makes MR imaging more appropriate than CT for performing multiple enterographic studies in a single patient. Likewise, it provides further incentive to devise and validate an MR enterography scoring system that can be used as an objective indicator of Crohn disease inflammatory activity and as an outcome measure in clinical trials.

Conclusions
MR enterography has the potential to play an important role in the management of small-bowel Crohn disease. MR enterography can demonstrate active small-bowel inflammation and complications such as bowel obstruction, penetrating disease, and abscess formation without the use of ionizing radiation. At present, MR enterography is most useful for assessment of symptomatic patients with known small-bowel Crohn disease. However, as techniques improve and undergo further validation and standardization, indications for MR enterography may expand to include assessment of response to therapy in clinical trials. When interpreting MR enterographic findings, familiarity with the MR imaging features of acute and chronic Crohn disease and their mimics improves diagnostic accuracy and helps optimize management of Crohn disease.

References


MR Enterography in the Management of Patients with Crohn Disease

John R. Leyendecker, M.D., et al

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We apply a multiphase multisection coronal SSFP MR sequence that covers the entire small bowel and colon. We generally acquire 15–25 phases per section location during free breathing. These images may then be displayed as a cine loop to assess bowel motility, exclude or confirm fixed stenoses and segmental dilatation, and detect adhesions. Because of the high image contrast, this type of sequence is helpful for assessing mesenteric vascularity and lymphadenopathy.

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These coronal contrast-enhanced images allow assessment of the vasculature, lymph nodes, and bowel wall enhancement. Enteric fistulas and abscesses also are depicted.

Page 1834
At MR enterography, submucosal edema in the small bowel appears as wall thickening and produces increased signal intensity on T2-weighted images. Mucosal and serosal enhancement, combined with intervening submucosal edema, contribute to a stratified or layered appearance on contrast-enhanced T1-weighted fat-suppressed images.

Page 1836
On cine images, fibrotic strictures appear as aperistaltic bowel segments that often demonstrate fixed mural thickening and luminal narrowing. The thickened submucosa of a strictured, fibrotic bowel segment does not typically display increased signal intensity on T2-weighted images in the absence of active disease because of the lack of mural inflammation and edema.

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A number of imaging features may lead to incorrect diagnoses when interpreting MR enterographic images. Although submucosal edema often is present in acutely inflamed bowel segments, it is not unusual to encounter extensive submucosal edema “upstream” from a high-grade obstruction. In such cases, acute inflammation may be present to some extent.