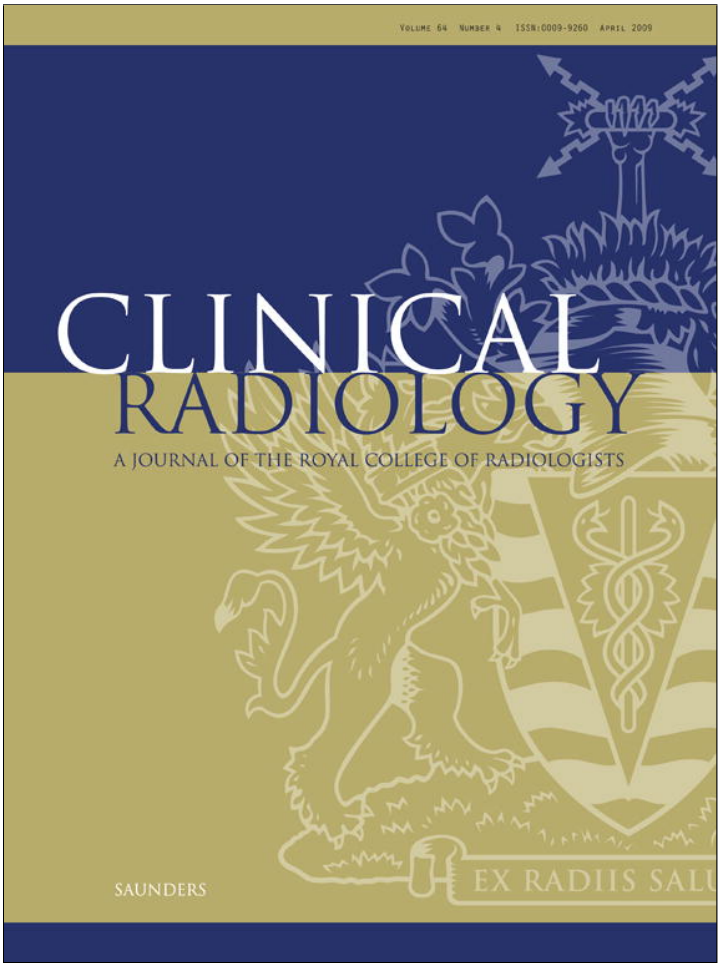
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REVIEW

Role of MRI in Crohn's disease

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The traditional imaging of Crohn's disease has relied on barium and computed tomography (CT) examinations. In recent years magnetic resonance imaging (MRI) has emerged as an imaging method that can be used in the diagnosis and assessment of Crohn's disease. The advantages of MRI include lack of ionizing radiation and its superior tissue contrast resolution. The clinical progression of Crohn's disease can be variable, and MRI can be used to assess inflammatory status, disease progression, and complications of Crohn's disease. MRI of the small bowel is an evolving technique and it has the potential to become the preferred technique for imaging of small bowel Crohn's disease in the future.

Introduction

Crohn's disease (CD) is a chronic inflammatory disease of the gastrointestinal tract that is characterized by ulceration, strictures, and fistula formation. CD commonly affects young adults and typically runs a chronic relapsing and remitting course. The indolent nature of the disease leads to frequent imaging examinations for monitoring disease activity and severity in order to guide appropriate treatment. The use of immune-modulating drugs has increased the need for accurate assessment of the activity and severity of disease.

Cross-sectional imaging investigations, such as computed tomography (CT) and magnetic resonance imaging (MRI) are particularly suited to assess the macroscopic features, extramural abnormalities, and complications. The high tissue contrast obtained using MRI, coupled with the absence of ionizing radiation, makes it ideally suited for imaging patients with CD. The purpose of this article is to review the role of MRI in CD. The advantages and disadvantages of MRI as compared with ultrasonography (US), CT, conventional enteroclysis (CE), and wireless capsule endoscopy (WCE) are also discussed.

Aetiology and clinical features

CD has a worldwide distribution but is more prevalent in Northern Europe and North America.[1] The disease most often afflicts young adults with the peak incidence between 15–25 years. A second lower peak has been reported in the 50–80 year age group.[2] Worldwide there is an equal sex distribution, although the female to male ratio is high when only colitis is considered. Extensive jejuno-ileitis is commoner in younger patients, whereas older patients tend to have localized enteritis. The precise cause is unknown, and therefore, a causal treatment is not yet available. However, there is evidence that the disease is due to an abnormal mucosal response to an unknown antigen.[3] Genetic factors may determine susceptibility to CD as up to 5% of patients have another affected family member.

The onset of CD can be insidious and patients may present with vague abdominal symptoms or complications arising from CD such as perineal

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sinuses, anorectal fistulae, or abscesses. Chronic diarrhoea is the most common presenting symptom; abdominal pain and weight loss are present in 70 and 60% cases, respectively, before diagnosis, whereas perineal fistulas are present in 10% of patients at time of diagnosis.

CD in the paediatric population may commonly present with systemic and extraintestinal rather than gastrointestinal symptoms. Isolated gastroduodenal disease is seen more commonly in paediatric patients and reported in 30–62% of patients on endoscopy and jejunal disease is also commoner in children as compared with adults.[4,5]

In the older age group, women are affected more frequently, and isolated involvement of the colon rather than small bowel is commoner.[5]

Pathological findings

The earliest macroscopic feature of CD is shallow aphthoid mucosal ulceration, histologically corresponding to early mucosal ulceration over a mucosal lymphoid follicle. CD most commonly involves the terminal ileum and ileocaecal region. Aphthous ulcers progress to frank ulceration, and in late stages, extensive linear and transmural ulcers may be present. Advanced ulceration with bulging of the oedematous residual mucosal islands leads to the "cobblestone pattern". CD involves the whole thickness of the bowel and also extends into the mesentery and the lymph nodes draining the bowel. The classic macroscopic features of long-standing disease include fat wrapping, stricture formation, mucosal cobblestoning, linear mucosal ulceration (classically on the mesenteric aspect of the bowel), deep mucosal fissuring, and fistula formation. Another feature of CD is the presence of clearly defined normal intestinal segments between diseased segments (termed "skip lesions") and this pattern of discontinuous involvement is considered pathognomic of CD.

Neoplasia in CD

There is increased risk for adenocarcinoma of affected intestinal segments and the risk of colorectal cancer in Crohn's colitis is four to 20 times higher than that of the normal population, with an incidence of up to 1.8%.[6,7] Defunctioned segments of bowel have higher risk for developing cancer. Carcinoma may present as a stricturing lesion that can be difficult to differentiate from benign strictures related to CD. Lymphoma has been reported to present as multifocal areas of increased nodularity and strictures on barium examinations.[8] Neoplastic lesions should also be distinguished from stricturoplasties as both may appear as annular lesions with shouldered margins.[9] Bowel cancer must be suspected when bowel obstruction in CD does not respond to conventional treatment and nasal decompression.

Role of MRI in CD

Several scientific reports have reported that the inherent tissue contrast resolution obtained on MRI can provide good mural and extramural detail.[10–19] Although as yet there is not enough evidence that MRI can identify early mucosal ulcers, some studies have shown that MRI has a good correlation with barium enteroclysis in demonstration of mucosal lesions.[10,20] MRI studies have reported sensitivities and specificities ranging between 88–98 and 78–100%, respectively, in the detection of CD. MRI has also been used in the detection and follow-up of CD in paediatric patients with sensitivity and specificity values 84–96 and 92–100%, respectively.[14,21]

MRI versus other diagnostic techniques

MRI versus CE. Prospective comparative trials between MR enteroclysis (MRE) and CE have reported sensitivity and specificity ranges for MRE of 82.5–89 and 100%, respectively, in the detection of bowel ulceration; 100 and 88–92.9% in the detection of stenosis; and 75–100 and 97.8–100% in the detection of fistulae.[13,22–25] A significantly higher number of abscesses, fibrofatty proliferation, lymphadenopathy, and skip lesions are detected on MRI than CE.[13,22,26] In their study, Umschaden et al.[26] report that in 24% of the patients MRI demonstrated abnormalities not seen at CE, whereas another study detected of 70% more abnormalities with MRE as compared with CE.[27] MRE can provide identical functional information regarding strictures and bowel obstruction as compared with CE.[26] A recent critically appraised article has concluded that MRE compares favourably with CE in terms of diagnostic yield but is inferior in detection of early mucosal abnormalities.[25]

MRI versus CT. There are no robust studies directly comparing CT with MRI in CD. One prospective study that directly compared MRE with CT enteroclysis (CTE) showed better overall agreement for CTE than MRE (0.52 versus 0.42).[28] However, in this study the proof of disease, as based on the findings at CTE combined with histological, surgical, laboratory, and clinical data, was not available for each patient and, therefore, accurate evaluation of reported sensitivity and specificity results cannot be performed. A comparison of contrast-enhanced MRI with CT using oral contrast media showed much higher sensitivity and specificity for MRI.[15] CT has high diagnostic sensitivity in suspected CD. Studies have reported sensitivities of 80–86.3% for CT when compared with CE, and 80–88% compared with ileocolonoscopy.[24,29–31] CT enterography has also been reported to be more sensitive than barium follow-through examinations in detection of active CD and extra-intestinal complications.[32] Early mucosal lesions (such as aphthoid lesions) are not accurately visualized on CT or MRI, making them less suitable as a first-line examination for suspected early disease. Extramural complications are well visualized on CT, although the higher contrast resolution of MRI makes it more suitable for the detection of fistulae and abscesses than CT.[24,33]

MRI versus WCE. A prospective comparative study between MR enterography (MREG), CE,and WCE has shown CE to be the least sensitive and WCE to be the most sensitive technique in the detection of CD.[34] MREG was less sensitive than WCE (83 versus 100%), although a statistically significant difference between the performance of WCE and MREG was not detected.

Many studies have reported a higher diagnostic yield for WCE compared with radiological investigations. A meta-analysis comparing imaging versus WCE has shown yields of 30 versus 69%, respectively.[35] However, the increase in use of WCE has also highlighted its limitations. Poor localization of bowel abnormalities, camera retention, contraindications in obstructive or stricture disease, and false-positive results are some of the significant drawbacks of WCE. Furthermore as CD, by nature, has significant transmural, extraintestinal progression, radiological investigations that provide mural and extramural detail provide complimentary information to the WCE examination.[36,37]

MRI versus push enteroscopy. Double-balloon or push enteroscopy have also been advocated for evaluation of the small bowel. The advantages of this method are the ability to directly visualize the bowel mucosa and biopsy suspicious lesions. The disadvantages include patient discomfort and long examination times. A pilot series has reported comparable findings for MRE and double-balloon enteroscopy in CD.[38]

MRI versus US. The advantages of US include its non-invasiveness and widespread availability. However, the significant disadvantages include operator dependence and the difficulty of viewing the gastrointestinal tract in its entirety. US has high sensitivity in detection of CD, particularly disease involving the terminal ileum. In a meta-analysis, the sensitivity and specificity ranges of an US examination were reported to range between 75–94 and 67–100%, respectively.[39]

MRI versus scintigraphy. Several studies have reported the use of labelled-leukocyte imaging in detecting CD and assessing its inflammatory activity.[40–43] Labelled leukocytes are used because mucosal infiltration with leukocytes is typically present in active CD. Tc-99 m HMPAO is a commonly used agent because of its greater availability, better image quality and lower radiation dose.[44–46] Direct comparative studies between MRI and scintigraphy have not been reported, although the sensitivity and specificity of leukocyte-labelled scintigraphy has been reported to range between 76–94.7 and 77.8–93.3%, respectively.[23] In recent years 2- [^{18}F]-fluoro-2-deoxy-D-glucose positron-emission tomography (FDG-PET) has been used to assess inflammatory activity in CD.[47–49] Neurath et al.[49] reported strong correlation between MRI and FDG-PET findings in CD, although reported lower specificity values for MRI.[49] The usefulness of PET in differentiating between active and indolent CD is unclear and its role in diagnosis of CD needs evaluation in larger studies.

Overview of imaging techniques versus MRI

Overall imaging techniques (US, MRI, scintigraphy, or CT) have high per-patient sensitivity (84.3–93%) and specificity (84.5–95.6%) for the diagnosis of inflammatory bowel disease; although CT had a significantly lower sensitivity and specificity compared with MRI and scintigraphy on a per-segment basis. Therefore, it may be justified to use any of these methods based on their advantages and disadvantages and local expertise.

Although CT is widely used in CD, it does carry a high radiation burden and the results of a recent meta-analysis conclude that it is preferable to use a non-ionizing technique, such as US or MRI, in CD.[23] A recent study has highlighted the high cumulative radiation dosages imparted to patients with CD, mainly due to the increased use of CT.[50] In this study CT accounted for up to 84.7% of the cumulative dose imparted to patients and 15.5% of patients had cumulative dosage in excess of 75 mSv. The carcinogenic effect of radiation can be particularly significant in patients with CD who already have an increased risk of developing gastrointestinal, hepatobiliary cancer, and small bowel lymphoma.

Among the non-ionizing techniques, the advantages of MRI over US include multiplanar imaging ability, comprehensive assessment of the entire gastrointestinal tract and easier follow-up of disease with MRI images. The ability to distinguish fibrotic from inflammatory strictures and high sensitivity for detecting abscesses and fistulae are the other important advantages. The disadvantages of MRI are its longer examination time and lack of consensus regarding oral contrast agents and timing of image acquisition in the enterographic technique.

MRI technique

The cardinal principle behind obtaining diagnostic small bowel images is good distension and opacification of the bowel lumen coupled with ultrafast MRI sequences and intravenous contrast. Collapsed loops of bowel can even hide large lesions and may appear falsely thickened. Distension of the small bowel can be achieved with intubation or non-intubation techniques. For the intubation technique (MRE) a nasojejunal catheter is placed at the duodeno-jejunal flexure and 1.5–2 l of iso-osmotic contrast medium is infused. Imaging of bowel is performed once contrast reaches the ileocaecal junction. MRE produces excellent distension of the bowel and can provide detailed luminal information that is useful in identifying early mural changes and also highlighting sub-acute or partial strictures. However, these advantages have to be counter-balanced by the complexity of the procedure and associated patient discomfort. Naso-jejunal intubation can be uncomfortable for the patient and sedation or anxiolytics may be needed.[51] MREG is another technique where a large volume of oral contrast medium is ingested by the patient prior to imaging. Although the enterographic technique may be less uncomfortable for the patient, it may not produce optimal and uniform distension of the bowel lumen. Consistent distension of the proximal bowel may also not be achieved on the enterographic technique as compared with the enteroclysis examination.

There is still no consensus on the amount of oral contrast medium needed for an enterographic examination and timing of image acquisition. Some studies have advocated long duration of contrast medium ingestion.[52] Other investigators advocate repeated imaging immediately after ingestion until the contrast medium reaches the terminal ileum before formal imaging sequences are performed. The second approach is less practical as it increases the amount of examination time needed for the investigation.[53] Kuehle et al.[51] studied the effect of different types and volumes of oral contrast medium on bowel distension and timing of image acquisition and found that good distension of the bowel was achieved with 1350 ml contrast medium (1.2–2% sorbitol solution and 0.2% locust bean gum) and no additional distension was achieved by increasing the contrast medium volume to 1800 ml.[65] Water was found to provide inadequate distension at all volumes. Ajaj et al.[54] reported no significant differences in bowel distension with either 1000, 1200, or 1500 ml mannitol solution. The optimal time for imaging the duodenum and proximal jejunum has been reported to range between 0–15 min, whereas the distal jejunum and ileum can be appropriately imaged between 20–35 min after contrast medium ingestion.[51] Lohan et al.[55] has reported a mean time of 55 min for imaging and recommends initial imaging at 20 min after contrast medium ingestion to assess progress of the contrast medium bolus and adjusting the timing of the examination accordingly.

Patients prefer MREG over MRE because there is less abdominal discomfort and nausea.[56,57] Furthermore, patients are still exposed to radiation during placement of the naso-jejunal catheter and the logistics of using two diagnostic rooms in tandem needs to be considered.

The sensitivity of MREG for diagnosing CD has been reported to be lower than the sensitivity of MRE ($p = .046$), whereas specificity values are comparable.[23] However, a prospective, randomized study showed a similar diagnostic sensitivity for MREG as compared with MRE (88 versus 88%), and recommended enterographic examinations for follow-up of established CD.[56] In the paediatric population, MREG has been proposed as a less invasive technique as opposed to MRE. Studies have reported excellent patient tolerance of the MREG technique with high sensitivity and specificities in the paediatric subgroup of CD.[58–60]

Oral contrast media. Several enteral contrast agents have been described that include water, methylcellulose, or solutions containing locust-bean gum, mannitol, and polyethyl glycol. These agents work by retarding the resorption of water in the intestine. Superparamagnetic agents have also been used as oral contrast agents, and they work by altering signal intensity within the bowel lumen. Enteral contrast agents may be positive, i.e., they produce increased signal intensity within the bowel lumen, whereas negative agents cause a signal drop out. Biphasic agents behave as positive or negative agents depending on the imaging sequence applied. Studies have reported different advantages and disadvantages for positive and negative contrast agents, although there does not seem to be any significant difference in terms of diagnostic accuracy.[61] Combined small and large bowel MRI has also been proposed as a feasible and useful technique by some investigators.[62,63]

MRI sequences (Table 1). In recent years high-resolution, ultra-fast sequences based on steady-state precession have been emerged as the predominant technique for imaging of the small and large bowel in CD. Different manufacturers' call these sequences true fast imaging with steady-state with free precession (true-FISP), balanced fast field echo (FFE) or fast imaging employing steady state precession (FIESTA). These sequences are relatively insensitive to motion artefacts and provide uniform luminal opacification and high contrast between the bowel wall, lumen, and the mesentery. The disadvantage of these sequences is a black boundary artefact along the bowel wall that may mask small lesions or abnormalities. Fat suppression may help in reducing the effects of the black-boundary artefact. Hohl et al.[60] reported high sensitivity and specificity (93.3 and 100%) of true-FISP sequences in detecting inflammatory lesions of the small bowel, and this sequence had greater diagnostic accuracy than T1, T2, and half-Fourier axial single-shot fast spin-echo (HASTE) sequences (80, 53.3, and 13.3%, respectively). They reported that the true-FISP had a significant superiority in soft-tissue differentiation compared with other sequences.

Fast MRI sequences obviate the need for long breath-holds and thus reduce motion or respiratory artefacts. MRI images are also acquired using T2-weighted fast sequences based on rapid acquisition and relaxation (RARE). Different manufacturers call these sequences HASTE, or single shot fast spin echo (SSFSE). These sequences produce high contrast between the lumen and the bowel wall. These sequences also do not have the black-boundary artefact, although they are susceptible to motion artefacts produced by flow void. Due to *k*-space filtering effects, visualization of the mesenteric structures is impaired on these sequences.

Two-dimension (2D) or dimension spoilt gradient echo T1-weighted sequences are used to acquire contrast-enhanced images. Fat saturation can be used to increase contrast resolution and also allows better assessment of bowel enhancement.[64] Three-dimensional (3D) acquisitions allow thinner collimation and allow multiplanar reconstruction (MPR), but are more prone to artefact production. Contrast-enhanced sequences using 2D and 3D-FLASH (fast low angle shot) or volumetric sequences, such as VIBE (volumetric interpolated breath-hold examination) have been reported in scientific literature.

During the examination bowel paralysis is induced by intravenous injection of buscopan or glucagon. Changes in bowel kinetics can also be evaluated on MR fluoroscopy to demonstrate either an obstructive element or abnormalities in peristalsis. MR fluoroscopy can provide functional

Table 1 Overview of MR Sequences for small bowel imaging used by the authors

MRI sequences	1.HASTE with fat saturation (similar to SSFSE)	2.True-FISP with & without fat saturation (similar to FIESTA; bFFE)	3.HASTE with fat saturation (similar to SSFSE)	4. Contrast-enhanced 2D FLASH or 3D VIBE with Fat Saturation
Plane	Coronal	Coronal and axial	Coronal and axial	Coronal and axial unenhanced and enhanced (60 s after contrast medium administration)
No. of sections	1	19–25	19–25	64
Section thickness (mm)	50	4	4	1.5
Field of view (mm^2)	512 × 512	512 × 400	512 × 512	288 × 312
Repetition time (ms)	5000	2.5–4.0	1200	2.5–5.12
Echo time (ms)	1080	1.6–1.8	80	1–2.5
Flip angle (°)	90–140	50–80	90–140	10–20

MR enterography - Patients drink 1300 ml mannitol solution divided in two aliquots. Each aliquot is drunk over 25 min and patient imaged at 55 min with sequence 1 to assess progress of contrast. If ileo-caecal region is opacified, buscopan is injected and sequences 2–4 performed. Small field of view, thin-section, true-FISP sequences are performed for abnormal bowel segments for further characterization of disease.

MR fluoroscopy can be performed using sequence 1 imaged every 6–8 s or single-section true-FISP (true fast imaging with steady-state with free precession) sequences.[HASTE, half-Fourier axial single-shot fast spin-echo; SSFFE, single shot fast field echo; FIESTA, fast imaging employing steady state precession; bFFE, balanced fast field echo; 2D, two-dimensional; FLASH, fast low angle shot; 3D, three-dimensional; VIBE, volumetric interpolated breath-hold examination.]

information regarding bowel motility and may help distinguish between fibrotic strictures and functional bowel spasm.

Accuracy and significance of MRI findings

Active inflammatory disease

Inflammation, superficial and deep ulcers, and transmural inflammation with granuloma formation characterize this category of disease. As yet there have been no reported comparative studies to suggest that MRI can consistently detect the early erosions or ulcers in CD as seen on double-contrast conventional enteroclysis studies. Aphthous ulcerations are readily seen on barium studies as usually a double-contrast medium technique is used (barium—air or barium—methylcellulose combination) that outlines irregularities of the mucosal contour. Cross-sectional examinations, such as CT or MR studies, depend on luminal distension using a single contrast agent, and this precludes detection of small mucosal lesions. Some studies have described the appearance of aphthous ulcers on thin-section MRI images as a nidus of high signal surrounded by a rim of moderate signal intensity.

Advanced inflammation in CD manifests as deep ulcerations and a cobblestone mucosal appearance. These are seen as linear, high signal intensity protrusions into the bowel wall (Figs. 1,2). Sensitivity values between 75—90% for the detection of bowel ulceration have been reported.[10,12,22,65]

Bowel wall thickening is a significant feature of CD, although not entirely specific. Small bowel wall thickness greater than 3 mm should be considered to be abnormal and has been reported to have sensitivity and specificity ranges of 83—91 and 86—100%, respectively. The detection of transmural ulcers and bowel wall thickening also has high inter-observer agreement that indicate that consistency and reproducibility of MRI in CD.[65] Gourtsoyiannis et al.[12] ranked the product of bowel wall thickness, lymph node enhancement, and intestinal ulcers as having the strongest correlation with active CD. The degree of bowel wall thickening and enhancement also has high degree of correlation with Crohn's disease activity index (CDAI) and histological grading. Sempere et al.[66]compared MRI findings of bowel wall thickening and enhancement in patients with active and quiescent CD, and found significant correlation between the degree of enhancement and thickening compared with CDAI. Koh et al.[67] reported a sensitivity of 91% and a specificity of 71% for active CD, whereas using the CDAI the sensitivity was 92% and specificity 28% in the same study. Assessment of inflammatory activity is also required to monitor the effects of medical therapy and immune-modulating agents. Furthermore, MRI is useful in excluding abdominal abscesses or septic foci prior to

Figure 1 A 55-year-old with histologically proven CD. Coronal image from an MREG examination obtained using true-FISP sequence (3.8/1.6/60°, 2 mm section thickness) of the ileum shows marked bowel wall thickening. Early ulcers are seen as areas of low signal causing disruption in the mucosal layer (arrowhead). Another ulcer shows lateral extensions in the submucosa (arrow).

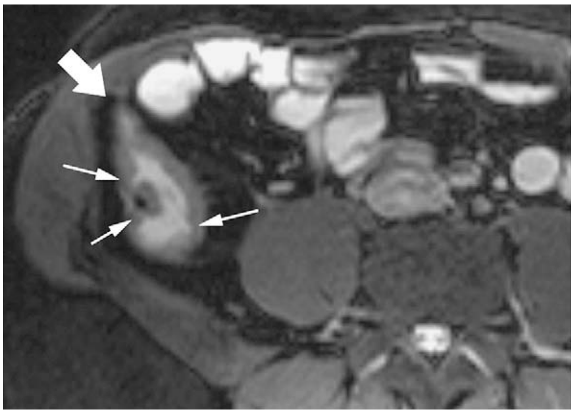


Figure 2 Transmural ulcers on MREG examination. Axial image obtained using true-FISP sequence with fat-saturation (5.7/2.3/80°, 2 mm section thickness) shows deep ulcers (arrows). One ulcer has traversed the bowel and an early entero-cutaneous fistulation is visible (thick arrow).

initiation of therapy with immunomodulators, such as infliximab.

''Cobblestone appearance'' of the intestinal mucosa is the result of longitudinal and transverse ulcerations of the bowel wall. The residual mucosa enhances after contrast medium administration and may show a criss-cross or striated pattern along the longitudinal axis of the bowel.

Active inflammation is associated with mucosal hyperaemia that is readily appreciated on MRI after intravenous contrast medium (gadolinium) administration as intense mural enhancement. The peak signal intensity of the mural enhancement has been shown to have good correlation with CDAI.[15,68,66,67,69–71] The enhancement pattern of the inflamed bowel has also been studied to assess inflammatory activity as compared with clinical indices and good response to medical treatment is reflected in a reduction in the intensity of bowel enhancement.[66,69] A layered pattern of bowel enhancement has been reported to have good correlation with active inflammation.[22,68,67] This ''layered'' appearance comprises of an inner enhancing ring produced by the hyperaemic mucosa; an outer ring by enhancing muscle and serosa with an intermediate low-density ring is produced by submucosal oedema (Figs. 3,4). A similar target appearance may be produced by a low signal intensity ''halo'' produced by fat hypertrophy and fibrosis of the submucosa in chronic inflammatory bowel disease. In these cases the submucosa has a dark, hypointense signal, especially on fat-suppressed sequences. It is important to distinguish between spasm and strictures caused by active inflammation and the fat-halo sign of chronic CD (isointense versus hypointense submucosa), as obstruction and spasm in active disease may be relieved by medical treatment, whereas chronic strictures may require surgical intervention. Fibrotic strictures have been reported to demonstrate irregular mural enhancement. This pattern of different enhancement has been attributed to differently expressed mediators in active and inactive CD.[72]

Distended, enhancing, mesenteric vessels supplying the inflamed bowel segment produce the ''comb sign'' akin to that seen on CT examinations (Fig. 5). A secondary finding associated with bowel inflammation is ''fat-wrapping'' or ''fat proliferation'' around the inflamed bowel.[73,74] This fibrotic and fatty proliferation of the mesentery leads to increased separation of bowel loops. Increased enhancement of the mesenteric fat around a bowel segment is a secondary sign of active bowel inflammation.[75]

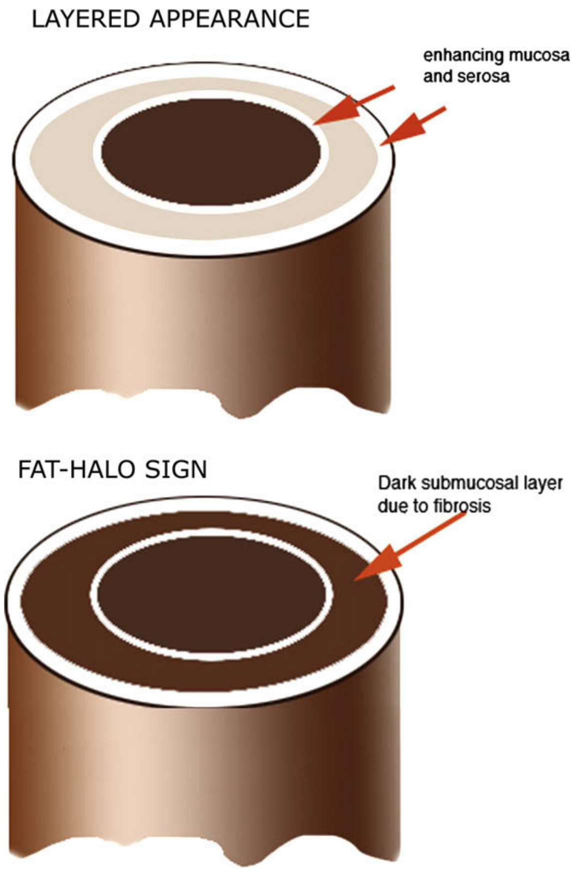


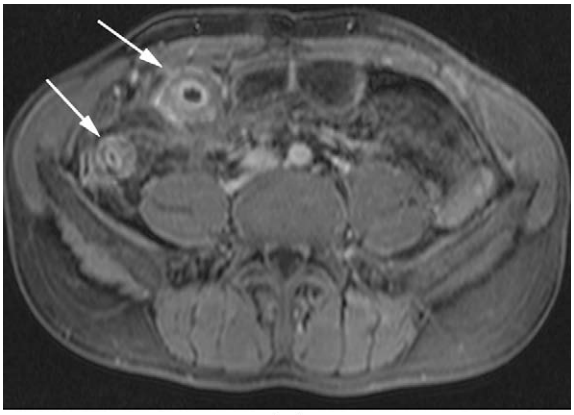
Figure 3 Schematic diagram showing target and halo signs seen in inflammatory bowel disease.

Fistula forming/perforating disease

This subtype is characterized by severe inflammation with progression from transmural ulceration to fistulation. Deep transmural ulcers eventually penetrate bowel muscle layer and cause subsequent inflammation in the adjacent mesenteric tissue leading to formation of small peri-intestinal abscesses and blind-ending sinus tracts. These tracts may track through the wall of an adjacent hollow organ and form a fistula (Fig. 6). Sinus tracks manifest as nodular irregularities and spiculations of the bowel wall. Larger sinus tracks and fistulae may be outlined by enteral contrast medium and are seen as linear tracks of high signal intensity.

Fistulas occur in up to 35% of patients with CD at some time during the course of their disease and in one third of patients within 10 years. The lifetime risk ranges from 20–40%.[76–78] Fistulas can be external or internal, and most fistulas occur in the perianal region (54%).[77] The reported sensitivity and specificity values for detection of internal fistulae range between 83.3–84.4 and 100%, respectively.[61,79]

Intestinal fistulae by themselves are not a primary indication for surgery. Surgery is indicated if



(a)

(b)

Figure 4 Contrast-enhanced, axial, T1-weighted, 3D source image obtained on an MREG examination with volumetric interpolated breath-hold examination (5.3/2.4/10°, 2.5 mm section thickness) shows the inflamed terminal ileum with layered enhancement (arrows) comprising of enhancing mucosa and serosa with the isointense, oedematous, submucosal layer in between (b) Axial, T1-weighted, 3D source image obtained with volumetric interpolated breath-hold examination (5.3/2.4/10°, 2.5 mm section thickness) shows the fat halo sign of chronic Crohn's disease manifesting as enhancing mucosa and serosa with a dark, hypointense submucosal layer.

Figure 5 MREG examination in a 55-year-old woman with CD. Coronal image obtained using true-FISP sequence (5.7/2.3/80°, 4 mm section thickness) shows the thickened, inflamed segments of the ileum with associated engorged mesenteric vessels producing the ''comb sign''. Note separation of bowel loops due to fat proliferation of the mesentery.

fistulae connect to the renal tract causing renal impairment or infection; if their drainage is cause for personal embarrassment and hygiene; or if they create a significant bypass resulting in intestinal malabsorption. The global assessment of the bowel along with MPR images can also be of help in planning surgical treatment.

Abdominal abscesses and inflammatory masses are less frequent than fistulae but are more often an indication to operative intervention. Smaller abscesses may be treated with antibiotics or drained percutaneously under CT or ultrasound guidance. Percutaneous, image-guided drainage may obviate the need for surgery in a significant proportion of patients.[80]

Fibrostenotic disease

This pattern of disease is typically characterized by bowel obstruction. On MRI a fixed narrowing of the affected segment without any significant bowel wall thickening or inflammation is seen. Chronic fibrotic strictures are typically hypointense on both T1 and T2-weighted sequences (Fig. 7). Fibrotic strictures may show minor, inhomogeneous contrast enhancement without any evidence of oedema or surrounding mesenteric inflammation or hyperaemia. MRE combined with MR fluoroscopy can provide functional assessment of bowel obstruction and strictures similar to those obtained on CE with less patient discomfort.[26]

Commonly the obstruction is caused by a single stricture and treatment is carried out by resection and primary anastomosis.[81] The terminal ileum is the commonest affected location requiring surgery and accounts for up to 40–50% of cases referred to surgeons. Furthermore, one third of patients have recurrent disease after ileocolic resection within 10 years.[82] MRI can provide useful information in this setting by differentiating between fibrotic and inflammatory strictures.[64]

Figure 6 MREG examination showing sinuses and fistulae. Coronal image obtained using true-FISP sequence with fat-saturation (5.4/2.3/80°, 2 mm section thickness) shows multiple linear inflammatory sinuses (arrows) arising from the terminal ileum and a sinus that has progressed to fistulation by communication with the adjacent bowel (ileo-ileal fistula) (arrowhead).

Perineal CD

It is estimated that perineal fistulas occur in 30—50% of patients with CD and patients with rectal CD have almost a 100% incidence of perineal fistulas.[83] The role of MRI in the diagnosis and in delineating the anatomy of perineal fistulae and inflammation has been extensively covered in scientific literature.[84,85]

Future potential

Higher field strength magnets and emerging techniques, such as parallel imaging, may help in improving spatial and temporal resolution on MRI. It is possible that with parallel imaging high-resolution 3D datasets comprising isotropic voxels of the entire abdomen could be produced within a single breath-hold.[86] Hohl et al.[87] reported the value of parallel-imaging sequences that enable acquisition of whole-body images within one breath-hold. 3D datasets would enable high-resolution MPR

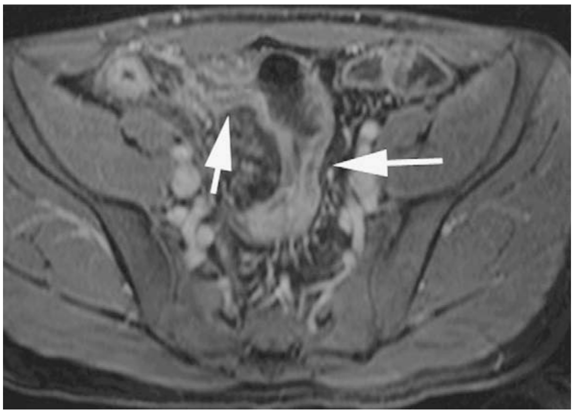


Figure 7 A 33-year-old man with CD and obstructive symptoms. Contrast-enhanced, axial, T1-weighted, 3D source image obtained with volumetric interpolated breath-hold examination (5.3/2.4/10°, 2.5 mm section thickness) shows multiple strictures in the distal ileum (arrows). The strictures show minor, inhomogeneous contrast enhancement and hypointense signal is seen in the submucosal layer indicative of fibrosis. Note lack of oedema or inflammation in the surrounding mesenteric fat.

reconstructions. Parallel imaging techniques also have the potential for improving dynamic imaging (such as MR fluoroscopy) due to their greater temporal resolution combined with high spatial resolution.

Conclusion

The advantages of MRI in CD include its high sensitivity in diagnosis of disease and important role in assessment of inflammatory activity. The ability to distinguish fibrotic from inflammatory strictures and high sensitivity for detecting abscesses and fistulae are the other important advantages that can help in guiding medical or surgical treatment of patients.

Its non-ionizing nature is a particularly significant advantage. In the authors' opinion, MRI examinations should be the preferred cross-sectional technique in CD in view of the high radiation dosage imparted during CT examinations.[88] Workforce limitations and expertise permitting, MREG with its higher patient acceptability can provide a valid alterative to barium or CT examinations in the imaging of patients with CD.

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