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UPDATE

Ulcerative colitis: value of MR imaging

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Abstract

Recent technologic advances have greatly improved the quality of abdominal magnetic resonance imaging (MRI) by allowing the identification of abnormalities in inflammatory bowel disease. Thus far, the role of MRI has been extensively investigated in Crohn disease (CD) and, to a minor extent, in ulcerative colitis (UC), likely due to intrinsic differences between these two diseases. In UC the inflammatory lesions, unlike CD, are confined to the colon, have a predictable spreading, and affect only the inner wall layer; thus endoscopy alone can assess the extent and severity of disease in most cases. However, preliminary studies have demonstrated that MRI also can be a reliable diagnostic tool for UC because it is useful for integrating clinical and endoscopic data. MRI can be valuable in distinguishing CD from UC in uncertain cases by assessing the sparing of the distal ileum and the continuity of colonic involvement. Moreover, MRI can provide important information if endoscopy is incomplete, e.g., due to tight strictures, or contraindicated, e.g., in severely acute disease, due to a high risk of perforation. MRI can detect most of the typical findings of the diseases, such as wall thickening, mural stratification, loss of haustrations, and several complications including fibrotic or neoplastic strictures. In addition, MRI can be extremely valuable in assessing disease activity by monitoring the degree of wall gadolinium enhancement and T2 signal at the level of the affected bowel segments, thus influencing pharmacologic and surgical planning. In the next few years, MRI will likely become the imaging modality of choice in the clinical management of this disease.

Key words: Ulcerative colitis—Magnetic resonance imaging—Inflammatory bowel disease—MRI of the colon

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The term *inflammatory bowel disease* (IBD) refers to Crohn disease (CD) or ulcerative colitis (UC); both share an unknown etiology and a chronic relapsing/remitting course that lasts for a patient's lifetime and together represent the vast majority of enterocolitides in Europe and North America.

UC is a chronic, idiopathic, inflammatory disease of the rectal and colonic mucosa, with continuous spreading and a predictable course and localization that extends from the rectal tract proximally to involve different portions of the colon (ulcerative proctitis, sigmoiditis, left-side colitis, or pancolitis). Rectosigmoid involvement is present in 95% of patients at endoscopy, whereas mucosal inflammation of the terminal ileum, the so-called backwash ileitis, is rarely observed [1].

UC at histology is characterized by a contiguous inflammatory progression, with aphthoid ulcers, mucosal edema, lymphocyte infiltration, and disruption of mucosal elements without extra-wall lesions [2]. This kind of chronic inflammatory bowel process determines a moderate wall thickness, usually submucosal sparing, fatty deposition in the submucosal layer, loss of haustration, widening of the rectosacral space, and several severe complications such as toxic megacolon, bowel strictures, perforation, and colorectal cancer [3].

The diagnosis of UC is based on clinical and laboratory findings but, above all, on endoscopic evaluation of the colon with multiple biopsies [3]. Because the disease is confined to the colon and affects only the inner wall layers, in the great majority of the cases endoscopy alone can assess the extent and severity of disease in UC, differently from CD.

If UC can be completely evaluated at endoscopy, then what role can cross-sectional imaging play in the assessment of this disease, in particular magnetic resonance imaging (MRI)?

Recent technologic advances have greatly improved the quality of abdominal MRI by allowing the identification of wall changes in several bowel diseases. Rapid acquisition sequences, phased array coils, signal modulation (e.g., selective suppression of fat tissue signal),

availability of positive, negative, or biphasic intestinal contrast agents, the intrinsic capability of acquiring images in multiple planes with different imaging parameters (e.g., T1 and T2 weighting), the inherent high soft tissue contrast, and lack of ionizing radiation currently make MRI a valuable diagnostic tool in the evaluation of IBD, in particular CD [4–6]. In recent years, many studies have confirmed the role of MRI in the evaluation of CD, in the detection of intestinal lesions and complications and the assessment of disease activity [7–16]. In contrast, the role of MRI in UC has been investigated less extensively [10, 17,18].

Despite their similar features, there are several intrinsic differences between CD and UC that can explain the different findings of the two diseases on cross-sectional imaging, in particular MRI, and the different interest and role that imaging can play in their assessment.

Technical considerations

In the evaluation of the bowel and the colon in particular, MRI should be performed with high field magnets, possibly at 1 to 1.5 T and preferably with a phased array coil.

Intestinal preparation and contrast agents

To avoid signal inhomogeneities related to residual stools, 18 h before the examination all patients should undergo colon cleaning with approximately 2 L of an isoosmolar water solution (e.g., polyethylene glycol solution), except those who have severe diarrhea.

To distend the lumen of the small and large bowels and to homogenize the lumen content, it is preferable to use an oral superparamagnetic contrast agent (suspension of iron oxide particles) that produces a negative effect on T1- or T2-weighted images [19]. Using a negative contrast agent improves evidence of wall gadolinium enhancement on T1-weighted images, whereas using a positive oral contrast agent decreases enhancement. Passage of contrast medium through the small bowel is usually extremely rapid in patients with CD or UC; therefore, less than 1 h is generally needed to obtain a homogeneous distribution of contrast medium throughout the small and large bowels (Fig. 1). Adequate opacification of the entire colon and rectum can be obtained 60 to 90 min after oral administration of 900–1000 cc of contrast agent; however, rectal insufflation of air helps to distend the lumen and to increase the negative effect throughout the entire colon. The negative effect of oral contrast medium is further improved by distending the colon with air because both determine a negative lumen (Fig. 2).

The use of a biphasic contrast agent such as polyethylene glycol as an intestinal contrast agent also has been advocated in IBD because it is more easily available and less expensive [13, 19, 20]. The effect of a biphasic agent, which is negative on T1 images and positive on T2 images, is valuable with T1-weighted imaging but less effective with T2-weighted imaging because the lumen signal usually remains inhomogeneous due to intestinal air and thus excludes an accurate evaluation of the inflamed wall. Moreover, a water enema can be difficult to perform inside an MR unit.

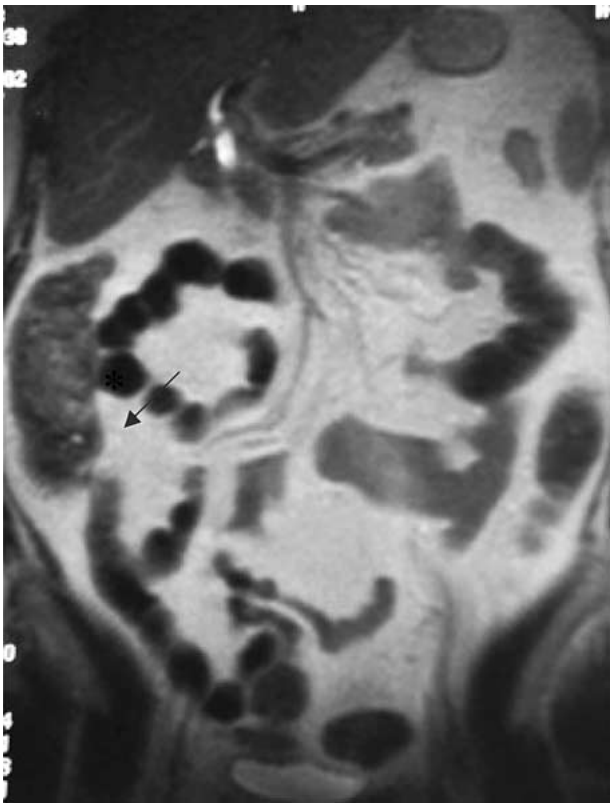

Fig. 1. Sparing of the distal ileum and normal ileocecal valve. The normal appearance of the ileocecal valve (*asterisk*) and terminal ileum (*arrow*) are important findings to differentiate UC from CD and are clearly displayed on this T2-weighteted half-Fourier single-shot turbo spin-echo coronal image that was obtained after oral administration of a superparamagnetic contrast agent.

T1-weighted sequences

Most MR studies on IBD are based on a preferential use of T1-weighted sequences after intravenous gadolinium injection [7, 9, 13, 14, 16].

MR assessment of IBD should always include T1-weighted sequences before and after gadolinium administration because these sequences provide an extraordinary display of the inflammatory changes typical of the disease, similar to those shown on contrast-enhanced computed tomography (CT). The degree of gadolinium enhancement at the level of the inflamed bowel wall has been reported to be an expression of the inflammatory activity of the disease [7, 11, 14, 16] (Figs. 2 to 4).

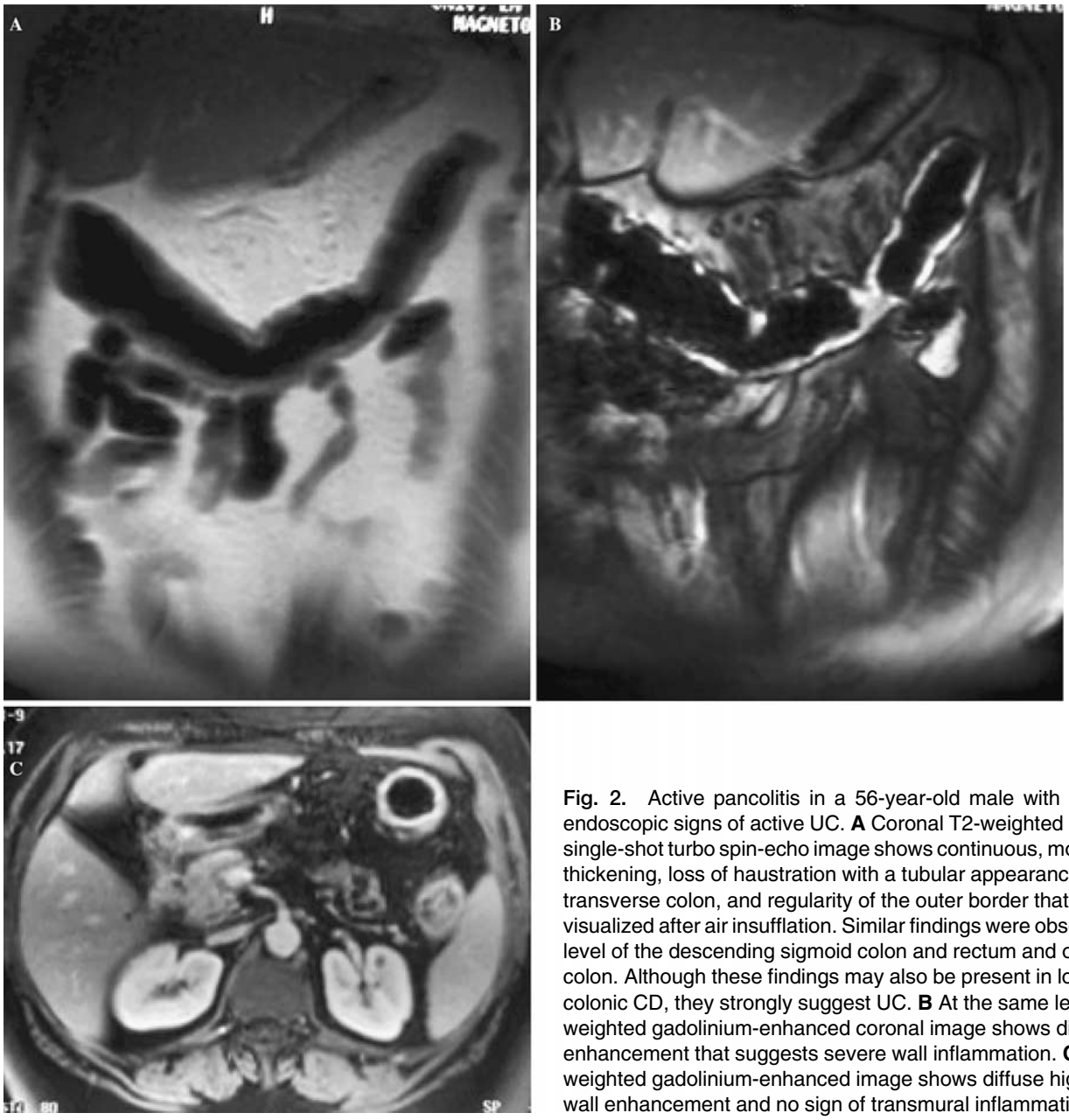

Fig. 2. Active pancolitis in a 56-year-old male with clinical and endoscopic signs of active UC. **A** Coronal T2-weighted half-Fourier single-shot turbo spin-echo image shows continuous, moderate wall thickening, loss of haustration with a tubular appearance of the transverse colon, and regularity of the outer border that is clearly visualized after air insufflation. Similar findings were observed at the level of the descending sigmoid colon and rectum and of the right colon. Although these findings may also be present in longstanding colonic CD, they strongly suggest UC. **B** At the same level, T1-weighted gadolinium-enhanced coronal image shows diffuse wall enhancement that suggests severe wall inflammation. **C** Axial T1-weighted gadolinium-enhanced image shows diffuse high-grade wall enhancement and no sign of transmural inflammation.

To obtain good quality T1-weighted images and satisfactory dynamic contrast enhancement during gadolinium injection, the use of fast breath-hold gradient echo sequences is suggested. These sequences are labeled in different ways in different MR systems, such as fast spoiled gradient echo, turbo field echo, or fast low-angle single shot, and are characterized by an acquisition time of approximately 1 s for each slice; usually 20 slices are acquired during a 18- to 27-s breath-hold. A delay of 60 s after gadolinium injection is usually adequate to obtain a good assessment of the wall and of the mesenteric vascularization.

Suppression of the fat signal is extremely helpful in the evaluation of wall enhancement after gadolinium injection, although it may obscure evidence of mesenteric lymph nodes. We suggest obtaining precontrast unsuppressed T1-weighted images and postcontrast fat-suppressed images (Figs. 2B, 3B, 4B, 5C).

T2-weighted sequences

T2-weighted sequences are very sensitive for studying inflammatory tissues, but only under adequate image conditions and with optimal imaging parameters and intestinal contrast agents [10, 11].

Half-Fourier single-shot turbo spin-echo T2-weighted sequences are commonly used in the evaluation of the bowel [21] because they are characterized by a short

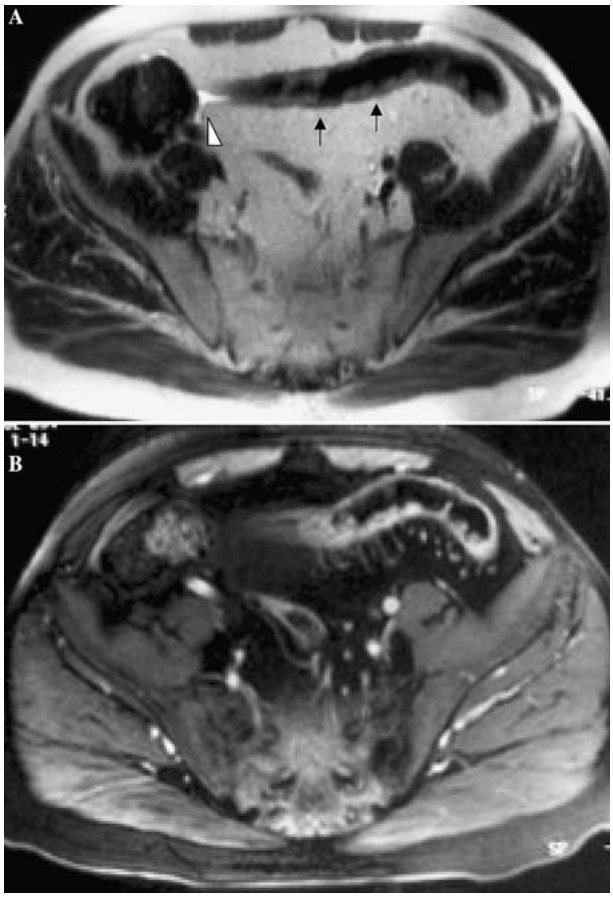

Fig. 3. Active UC of the rectosigmoid colon. **A** Axial T2-weighted half-Fourier single-shot turbo spin-echo image shows diffuse wall thickening of the sigmoid colon, with a regular outer profile and a waved inner profile (*arrows*), signs that are characteristic of UC. The waved inner profile suggests the presence of inflammatory pseudopolyps. A minimal amount of free fluid (*arrowheads*) and a possible adhesion to the medial cecal wall are evident on the right side. Active disease was diagnosed at the level of the entire sigmoid colon. **B** Axial T1-weighted fast low-angle single-shot post-gadolinium image shows similar morphologic changes with diffuse wall enhancement at the level of the sigmoid colon, suggesting active disease (printed with permission from Springer-Verlag, p. 211 [3]).

acquisition time of approximately 1 slice/s (20 slices are acquired during an 18- to 27-s breath-hold), high intrinsic contrast, and adequate spatial resolution (Figs. 1, 2A, 3A). Other commonly used T2-weighted sequences are high-resolution turbo spin echo (Figs. 4A, 5A) and T1- and T2-weighted true fast imaging with steady-state precession.

If T2-weighted sequences are acquired without an adequate intestinal contrast agent, images have poor contrast resolution because the bowel content displays a very inhomogeneous signal that ranges from very bright (fluid) to gray to very dark (air), a problem that is overcome by oral administration of a superparamagnetic contrast agent and/or by insufflation of air. Moreover, the bright signal of mesenteric fat can be darkened by using a fat-suppression technique in association with a superparamagnetic contrast agent. The use of fat suppression with T2-weighted turbo spin-echo images is useful to detect inflammation of the bowel wall and of the perivisceral mesenteric fat.

MRI findings in UC

Morphologic assessment of disease

The panoramic and multiplanar capabilities of MRI allow adequate assessment of the entire extent of disease [22]. Usually, colonic involvement of UC can be better assessed on axial and coronal planes, whereas rectal involvement is better depicted on axial and sagittal planes. The small bowel and the distal ileum in particular are well visualized on axial and coronal planes (Fig. 1). Classically, UC involves the rectosigmoid colon and extends proximally to involve the entire colon. Rarely the disease involves only the right colon, and the distal ileum may be inflamed in only approximately 15% of patients who are affected by pancolitis (backwash ileitis).

The tubular shape of the involved colon and loss of haustration, findings typical of longstanding disease, can be fully appreciated on coronal planes and usually better than on other imaging planes (Fig. 2).

Wall thickening and wall features

Thickening of the bowel wall can be easily visualized on T1- and T2-weighted sequences, preferably on axial images. The degree of thickening of the colonic wall is usually less in UC than in CD (Figs. 3, 4), with mean values of 7 or 8 mm versus 13 mm, respectively, as reported in CT studies [22–27]. However, marked thickening of the rectal or colonic wall that exceeds 10 mm can be frequently observed in active and severe disease (Fig. 2). The inner profile of the wall can show a waved configuration in UC (Fig. 3) or in CD (Fig. 4) on T2- and T1-weighted gadolinium-enhanced images, whereas the outer wall profile is sharper and smoother in UC than in CD due to intramural rather than transmural extent of the inflammatory process [22].

Wall stratification is another common finding of UC that is observed in approximately 60% of patients with UC versus 8% of patients with CD, as reported in previous CT studies [22–29]. Stratification is also detectable on MRI (Fig. 5) and is better observed on T2-weighted plain images as a bright wide line within the two dark stripes of the mucosal and muscularis propria, likely related to the increased presence of fat or edema in the submucosal layer.

Wall signal

By suppressing fat on T2-weighted images, it is possible to distinguish between submucosal fat and edema, thus

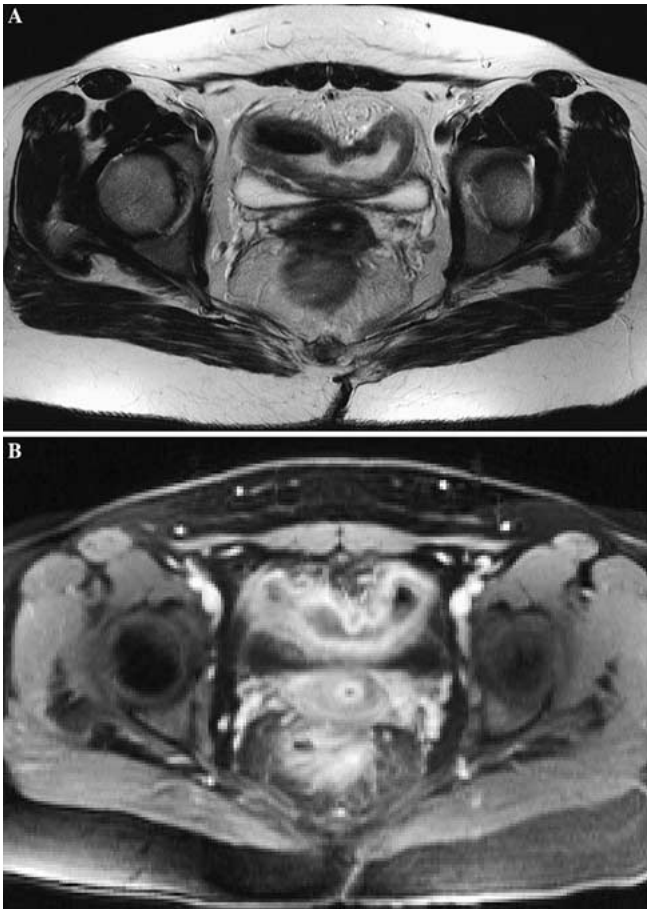

Fig. 4. Sigmoid colon in a 20-year-old female with CD and clinical signs of severe inflammation. **A** Axial T2-weighted turbo spin-echo image shows marked wall thickness of the sigmoid colon. **B** Axial T1-weighted fat-suppressed gadolinium-enhanced fast low-angle single-shot image shows marked wall thickening with evident irregularities of the outer border that are likely related to inflammatory adhesions, a distinctive sign of CD.

characterizing the wall inflammation and grading the activity of disease. In acute phases a persistent bright mucosal and submucosal signal on T2-weighted fat-suppressed images strongly suggests wall edema and active disease, whereas complete suppression of the submucosal signal suggests fat infiltration and quiescent disease [22, 30] (Figs. 5, 6).

Wall enhancement with gadolinium, as observed on T1-weighted fat-suppressed images, is one of the most relevant findings of IBD and is usually observed in active CD and UC. The degree of enhancement at the level of the inflamed bowel wall in UC is likely related to the degree of inflammatory activity, although this correlation has been proved only for CD [11, 14, 16]. According to our experience, in severe and active UC, wall enhancement is frequently associated with relevant wall thickening (Figs. 2, 3), whereas in moderate disease enhancement usually is evident but associated with less thickening (Fig. 5). In quiescent disease, enhancement can be nominal or absent (Fig. 6) [30]. It is important to emphasize that, in our experience, no abnormality can be detected in approximately 10% of patients who have proved quiescent UC.

Perivisceral abnormalities

Mesenteric fibrofatty proliferation at the level of the affected bowel is a typical finding of CD rather than of UC. However, a prominent perirectal fibrofatty proliferation with widening of the presacral space is frequently observed in UC and widely considered a feature typical of longstanding disease (Fig. 5). Moreover, mesenteric proliferation can be frequently observed at the level of the sigmoid colon and, to a minor extent, at the level of other colonic segments (Fig. 6). Although signs of perivisceral inflammation are typical of CD, it is not uncommon for T2-weighted images to display minimal amounts of free fluid outside the bowel in UC, which is suggestive of local serosal inflammation (Fig. 3); enteroenteric or enteroadnexal adhesions also can be observed in UC, although less frequently than in CD.

Complications

Severe fibrotic strictures can be clearly observed after air distention of the colon and can be characterized by their regularity and minimal enhancement. In contrast, neoplastic strictures, a well-known complication of longstanding UC, are characterized by eccentric and irregular wall thickening in the context of an extensively inflamed bowel wall (Fig. 7).

Postsurgical findings

In patients who are affected by UC after total colectomy and ileal pouch-anal anastomosis, wall inflammation can be observed at the level of the pouch itself, the so-called pouchitis. MRI is an excellent diagnostic tool to assess wall inflammation at this level and can detect possible complications such as strictures, adhesions, or phlegmons (Fig. 8).

MRI differential diagnosis between UC and CD

One of the major diagnostic issues in the clinical management of IBD is the differentiation of UC from CD, which is crucial in the choice of an appropriate pharmacologic therapy and for surgical planning, which is substantially different for the two diseases. This distinction is also important for prognostic reasons, to determine the likely course of the disease, effects of therapy, and the risks of recurrence and cancer.

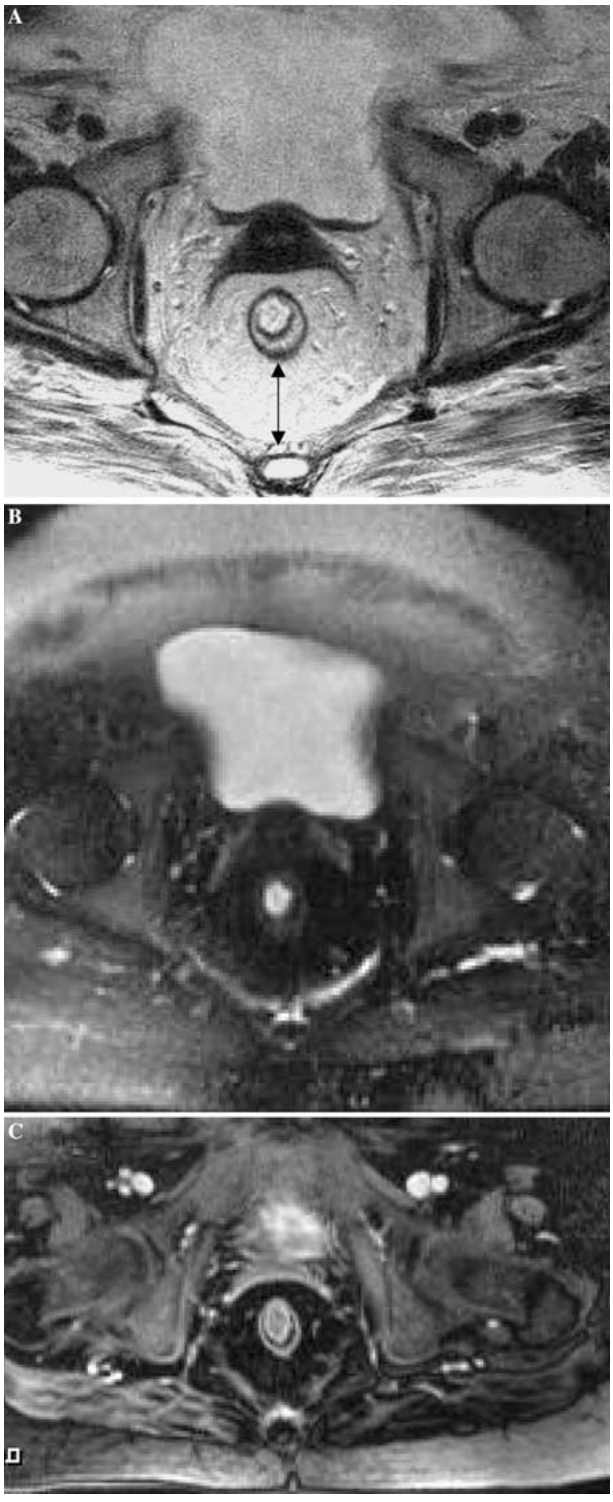

Fig. 5. Rectum of a 60-year-old female with longstanding UC and mild symptoms and signs at clinical and endoscopic evaluations. **A** Axial T2-weighted high-resolution turbo spin-echo image shows diffuse thickening of the rectal wall, with widening of the presacral fat (*double-headed arrow*). Mural stratification is also evident, characterized by a bright internal line (the submucosa layer) between two dark stripes that are related to the mucosa and the muscularis propria, respectively. **B** Axial T2-weighted fat-suppressed half-Fourier single-shot turbo spin-echo image, obtained at the same level as A, shows complete darkening of the perivisceral fat and suppression of the wall signal, suggesting minimal inflammatory wall involvement. At the level of the submucosal layer, the brightness observed on the plain image has been completely canceled, suggesting the presence of submucosal fat. On endoscopy only a few aphthoid ulcers were observed, with sparing of most of the mucosa. **C** Axial T1-weighted fat-suppressed fast low-angle single-shot post-gadolinium image shows moderate wall enhancement, with complete suppression of the signal of the submucosal layer, in agreement with findings observed on T2 saturation suppressed images.

CD is a chronic disease that involves discontinuously and unpredictably any portion of the gastrointestinal tract and more frequently the distal ileum, which is characterized by transmural inflammation of the bowel wall, with a tendency to extend to the mesenteric fat, thus leading to adhesions and fistulas [2, 3, 31]. The transmural extent of inflammation produces those typical signs of CD that are easily detected on cross-sectional images, such as marked wall thickening (< 20 mm), fibrofatty proliferation, and enlarged mesenteric lymph nodes, which are useful findings to differentiate CD from UC (Fig. 4). Whenever CD presents these typical intrinsic features, particularly if the small bowel is extensively involved with sparing of the colon, differentiation from UC is simple.

However, involvement of the colon can be found in more than 60% of patients with CD because it is frequently associated with involvement of the distal ileum (30% to 55% of cases) and exclusively limited to the colon in approximately 15% to 25% of cases [2]. The rectum may be involved in approximately 50% of patients with CD. Endoscopy and histology alone cannot always differentiate colonic CD from UC, mostly due to incomplete sampling of the bowel wall layers obtained from biopsy specimens, which are usually limited to the mucosal and submucosal layers. In these cases the final diagnosis of IBD should be based on a combination of clinical, radiologic, endoscopic, and histologic examinations.

MRI can play an important role in differentiating the two diseases because it is a reliable diagnostic tool in the assessment of CD lesions at the level of the small and large bowels [13–16]. MRI is in fact, a panoramic examination that can be used to assess the small and large bowels simultaneously, extremely sensitive to inflammatory bowel changes. For example, it can be helpful in the differential diagnosis between CD and UC by detecting sparing or involvement of the distal ileum (Fig. 1). The small bowel is generally normal in UC, although backwash ileitis in rare cases can be misleading. Nevertheless, a differential diagnosis is possible

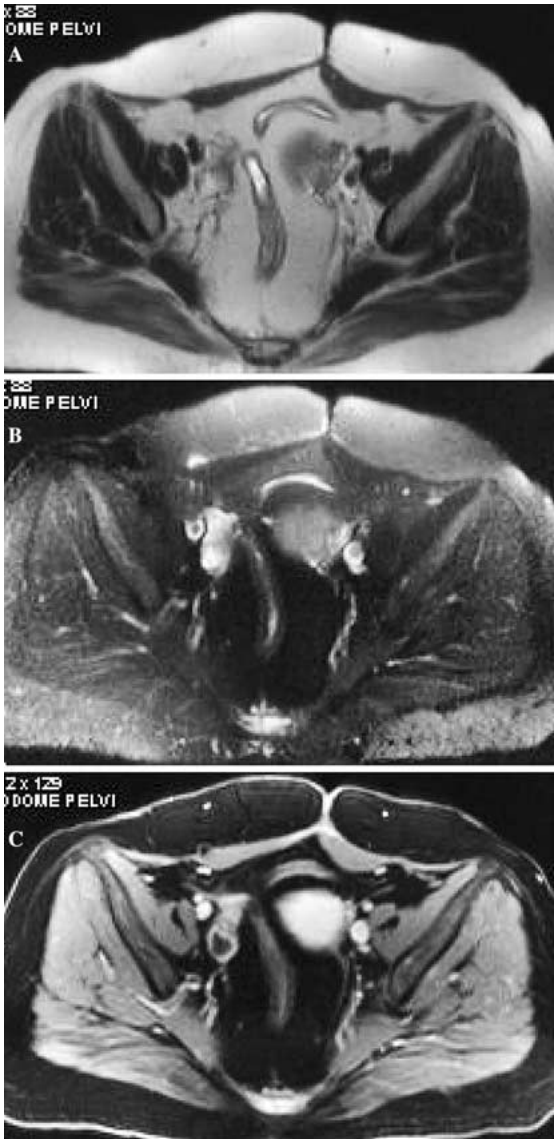

Fig. 6. Inactive sigmoid colon and rectum in a 45-year-old female with longstanding UC. **A** Axial T2-weighted half-Fourier single-shot turbo spin-echo image shows complete loss of haustration at the level of the sigmoid colon, with minimal wall thickening and a large amount of surrounding fibrofatty proliferation. **B** Axial T2-weighted half-Fourier single-shot turbo spin-echo fat-suppressed image displays complete darkening of the sigmoid colon wall, suggesting inactive disease. **C** Axial T1-weighted fat-suppressed gadolinium-enhanced fast low-angle single-shot image demonstrates lack of wall enhancement at the level of the sigmoid colon, thus confirming inactive disease.

because backwash ileitis shows a degree of wall inflammation generally lower than that in CD; in addition, it should be associated with a continuous involvement of the entire colon, which is quite uncommon in CD. Because 75% of patients with CD have some small bowel disease and only about 20% have only colonic involvement, evidence of a normal small bowel on MRI definitely favors UC.

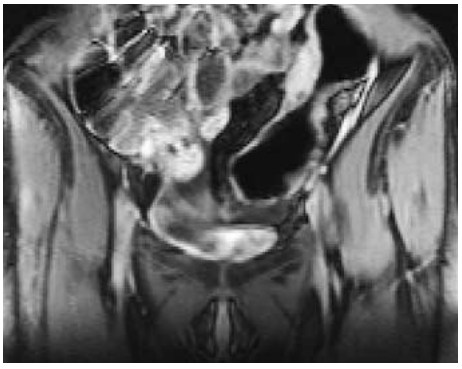

Fig. 7. A 45-year-old female with longstanding UC of the left colon (30 years) who complained of worsening symptoms and lower abdominal pain. Coronal T1-weighted post-gadolinium image demonstrates marked eccentric wall thickening of the sigmoid colon that produces a tight stricture and is strongly suggestive of carcinoma. This finding was confirmed at endoscopy and surgery.

Several other MRI findings regarding wall characterization may help in the differential diagnosis. For example, segmentary involvement of the colon or evidence of transmural disease favors the diagnosis of CD rather than of UC (Fig. 4). Wall thickening is always less in UC than in CD due to intramural rather than transmural extent of disease; the mean value is 7.8 mm in UC versus 11 mm (<20 mm) in CD. Moreover, the outer contour of the colonic wall is smooth and regular in 95% of patients with UC, whereas serosal and outer mural irregularities are found in 80% of patients with CD, as reported in previous CT studies [24–27]; these findings are commonly observed on MRI.

Inflammatory involvement of the mesenteric fat is more frequently found in CD than in UC. Fistulas or sinus tracts, adhesions, and abscesses are hallmarks of CD, and all are detectable on MRI with high accuracy.

Nevertheless, in some patients with chronic colitis, a precise diagnosis may not be possible clinically or histologically or with any diagnostic modality, including MRI, thus resulting in a final designation of ''indeterminate'' colitis. In these cases, MRI findings indicative of CD may be associated with findings typical of UC [32, 33].

Role of MRI in the management of UC

MRI is an excellent modality to investigate the entire bowel and can play an important role in the overall evaluation of IBD, a major field of interest for gastrointestinal radiologists [34]. The intrinsic properties of MRI, such as high contrast resolution, availability of

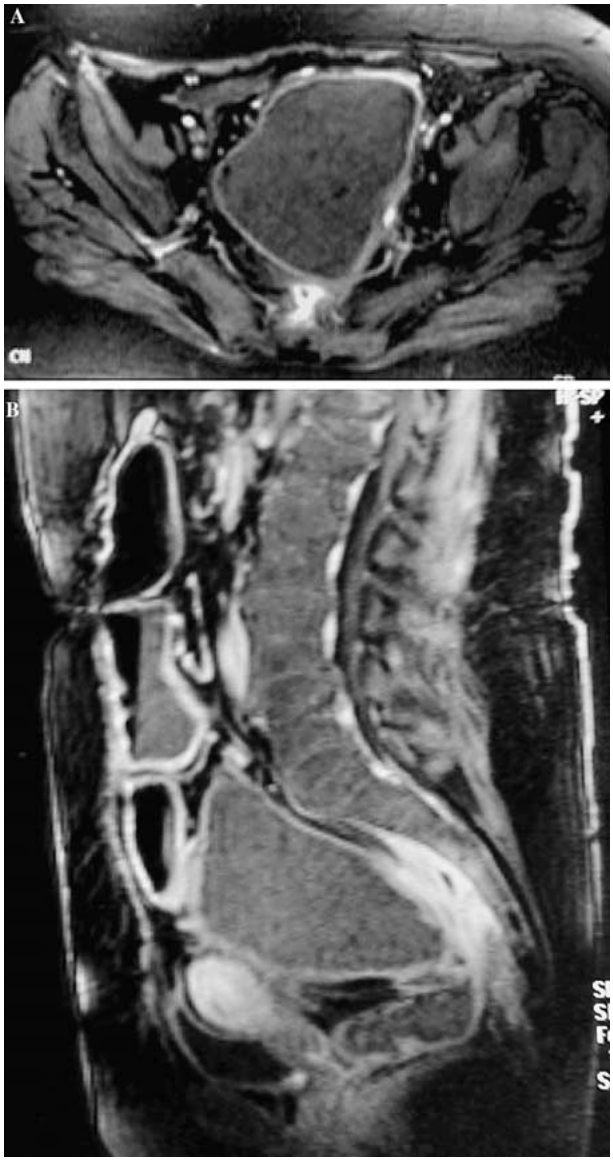

Fig. 8. A 70-year-old female after total colectomy for UC, with chronic endoscopic signs of inflammation at the level of the ileal pouch. Axial (**A**) and sagittal (**B**) T1-weighted gadolinium-enhanced images show the wide ileal pouch with moderate diffuse wall enhancement and thickness. In the presacral region, strongly enhancing inflammatory tissue is evident, suggesting a fistulous complication.

multiple imaging parameters, high sensitivity of T2-weighted sequences for inflammation, the possibility of modulating the signal by using fat suppression, and the excellent enhancement obtained after gadolinium injection make MRI a reliable diagnostic tool for CD and UC because it can detect most findings typical of these diseases and their complications.

MRI can be extremely valuable in distinguishing CD from UC in uncertain cases by assessing sparing of the distal ileum and the continuity of colonic involvement. Moreover, there are several additional differential findings that can further help to differentiate the two diseases. Although the extent of UC can be easily and completely assessed by endoscopy because the disease is limited to the inner wall layers and there are rare extraintestinal complications, MRI may play an important role whenever endoscopy is not feasible.

For example, MRI can assess the extent and severity of disease in the presence of fibrotic strictures that can prevent endoscopic evaluation of the entire colon, or in severe acute disease, when endoscopy may be incomplete or contraindicated. MRI evaluation of the degree of wall inflammation can be crucial during acute exacerbations of disease, when endoscopy is not recommended due to a high risk of bleeding or perforation, and when the decision of an urgent colectomy can be based on the effectiveness of medical treatment. MRI can evaluate the degree of inflammation on the basis of the intensity of gadolinium wall enhancement and T2 signal, it is safe and repeatable within short intervals, and can always be used to monitor the effects of pharmacologic therapy.

In patients who have undergone total colectomy and have ileal pouch-anal anastomosis, MRI can detect early signs of pouchitis, a frequent inflammatory complication after surgical repair.

In conclusion, on the basis of our experience and of preliminary studies, MRI seems to detect most morphologic changes and inflammatory activity of UC and thus will likely become the imaging modality of choice in the management of this disease.

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