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MR Enterography of Crohn Disease

MR Enterography of Crohn Disease: Part 2, Imaging and Pathologic Findings

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OBJECTIVE. The purpose of this article is to review MR enterography technique and imaging findings suggestive of Crohn disease on these examinations. This article will also allow the reader to self-assess and improve his or her skills in the performance and interpretation of MR enterography examinations.

CONCLUSION. This article reviews the technique of performing MR enterography examinations. MRI plays a valuable role in providing accurate information about severity of and complications related to Crohn disease and can help in guiding surgical or medical treatment.

Crohn disease has a worldwide distribution but is more prevalent in Europe and North America [1, 2]. The peak incidence of Crohn disease is in adolescents and young adults between 15 and 25 years old; a second shallow peak is seen in the 50- to 80-year-old age group [3, 4]. Disease is distributed equally between the sexes, although isolated colonic disease is more common in women than men. Older patients tend to have localized enteritis, whereas jejunoileitis is more common in younger patients [5].

The current view is that the diagnosis of Crohn disease is established by a nonstrictly defined combination of clinical presentation; endoscopic appearance; radiology, histology, and surgical findings; and, more recently, serology results [6]. A European evidence-based consensus group outlined characteristic macroscopic pathologic findings in patients with Crohn disease [6]. Detection of these macroscopic features of Crohn disease is particularly important for the radiologist because many of these features can be shown on dedicated MRI studies of the bowel.

Pathologic Findings

The earliest macroscopic finding in Crohn disease is aphthous ulceration of the bowel mucosa. The most commonly affected region is the terminal ileum and ileocecal region. Shallow ulcers proceed to frank ulceration, and later extensive transmural ulceration may be present. Deep ulcers may coalesce to form linear or transverse ulcerations. The presence of islands of normal mucosa interspersed between deep ulcers leads to the formation of a cobblestone pattern. Advanced inflammation typically involves the entire thickness of the bowel and also extends into the mesentery and the lymph nodes draining the bowel. The mesentery surrounding the affected segment becomes thickened because of inflammation and may become fibrosed in the late stage of disease. A pathognomic feature of Crohn disease is the presence of clearly defined normal segments between diseased segments, which is termed "skip lesions."

MR Findings

MRI can be used to show the pathologic findings of and complications related to Crohn disease. The varied behavior and clinical progression of Crohn disease have led to its subtyping by various investigators on the basis of inflammatory activity, clinical indexes, and histopathology results. However, classification by clinical or laboratory data has not been entirely reproducible. Maglinte and colleagues [1] proposed an imaging-based classification of Crohn disease, which they surmise could provide useful information when used in combination with clinical and laboratory data. They classify Crohn disease into four broad groups: active inflammatory, perforating and fistulating, fibrostenotic, and reparative and regenerative subtypes. The imaging findings in these subtypes are based on the detection of ulceration, fistulas, bowel edema, strictures, and extraintestinal abnormalities. MR enterography has the potential to

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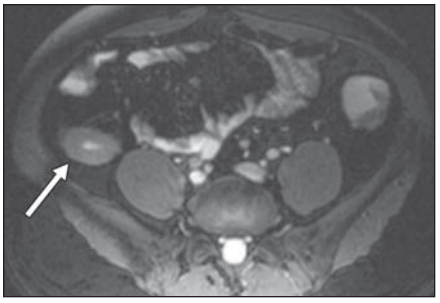

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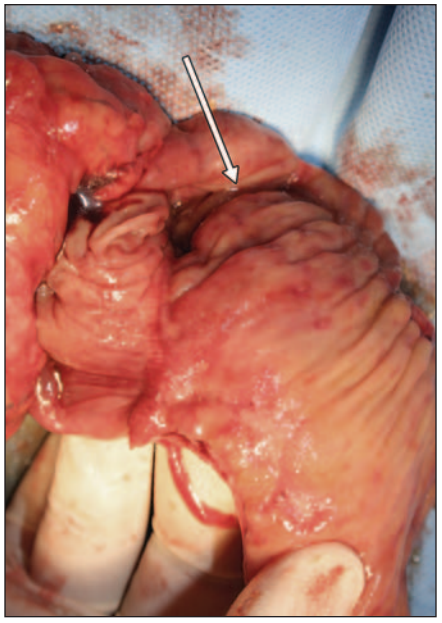

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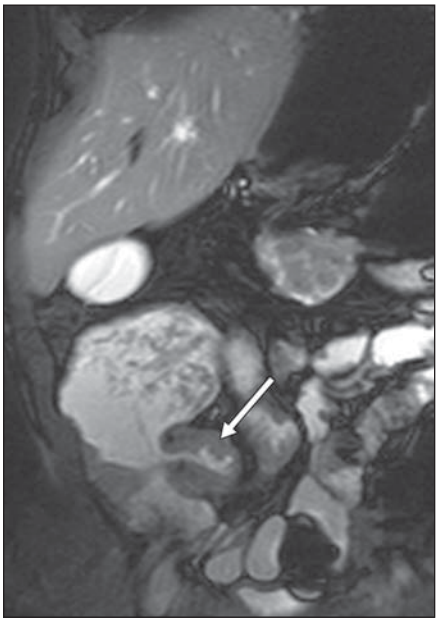
Fig. 1—32-year-old man with biopsy-proven Crohn disease.
A, Axial true fast imaging with steady-state precession image shows thickened terminal ileum (*arrow*).
B, Resected specimen shows inflamed thickened terminal ileum (*arrow*).

show these pathologic changes and therefore to provide accurate information that can help in guiding appropriate clinical therapy.

Active Inflammatory Disease

This subtype of disease is characterized by inflammation with superficial and deep ulcers, transmural inflammation with granuloma formation, and mural thickening (Figs. 1–5).

Intestinal ulcers—Cross-sectional examinations such as CT or MR studies depend on luminal distention using a single contrast agent, which precludes detection of small mucosal lesions or irregularities that are readily seen on double-contrast enteroclysis studies. An aphthous ulcer may be seen on high-resolution MR images as a nidus of high signal surrounded by a rim of moderate signal intensity [7]. The presence of aphthous ulcers provides strong evidence for Crohn disease in the appropriate clinical setting. Aphthous ulcers are also seen in other conditions such as infections, tuberculosis, and ischemic enteritis, but aphthous ulcers are encountered less commonly in these entities than in Crohn disease.



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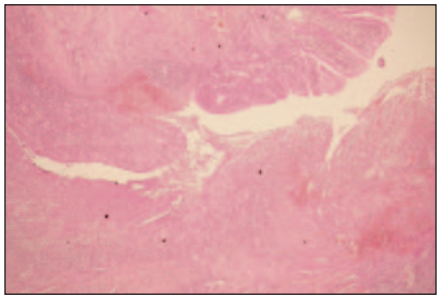

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Fig. 2—58-year-old woman with biopsy-proven Crohn disease.
A, Coronal true fast imaging with steady-state precession image obtained with fat saturation shows thickened, inflamed segments of ileum with deep ulcers seen as high-contrast protrusions within bowel wall (*arrow*).
B, Photomicrograph of histologic specimen shows deep, fissuring transmural ulcer in bowel wall.

Advanced inflammation in Crohn disease manifests as deep ulcerations and a cobblestone mucosal appearance. Deep transmural ulcers manifest as linear, high-signal-intensity protrusions into the bowel wall on fast imaging with steady-state precession (FISP) and HASTE sequences. These linear protrusions are formed by enteral contrast material outlining deep ulcers. True FISP images have a black boundary artifact that may mask smaller transmural ulcers, and occasionally HASTE sequences may highlight transmural ulcers with more facility because of the high contrast difference between the luminal contrast and the dark bowel wall. Sensitivity values for the detection of bowel ulceration have been reported in the scientific literature to be between 75% and 90% [8–10].

Another significant feature of Crohn disease is thickening of the inflamed bowel wall. Although this feature is not entirely specific for Crohn disease, any thickening of the small bowel wall greater than 3 mm should be considered abnormal. This finding has been reported to have sensitivity and specificity ranges of 83–91% and 86–100%, respectively, for Crohn disease. The detection of transmural ulcers and of bowel wall thickening has also been reported to have high interobserver agreement, which indicates the consistency and reproducibility of MRI findings in patients with Crohn disease [10].

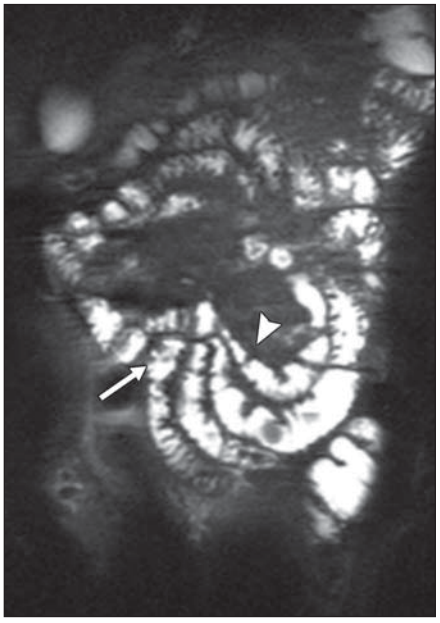
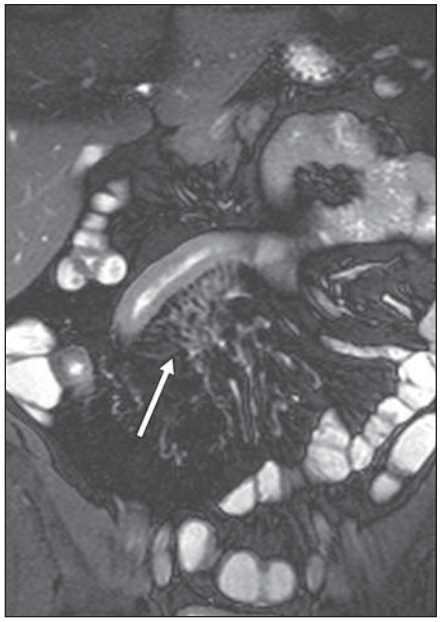


Fig. 3—47-year-old man with proven Crohn disease. Coronal HASTE image shows nodular (*arrow*), thickened, and asymmetric folds in distal ileum (*arrowhead*).



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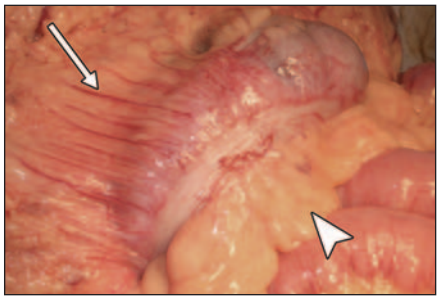

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Fig. 4—52-year-old woman in treatment for known Crohn disease.
A, Coronal true fast imaging with steady-state precession image obtained with fat saturation shows engorged mesenteric vessels surrounding inflamed distal ileum forming comb sign (*arrow*).
B, Intraoperative image shows fat wrapping (*arrowhead*) and hyperemia of inflamed segment (*arrow*).

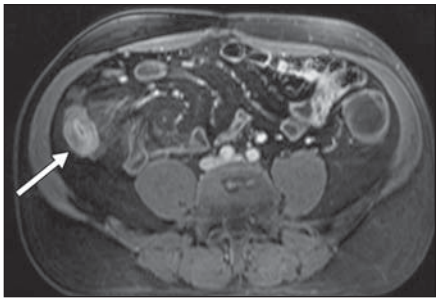


Fig. 5—35-year-old man with known Crohn disease and previous right ileocolic resection. Axial volumetric interpolated breath-hold examination image after IV contrast injection shows marked intestinal enhancement in neoterminal ileum with layered pattern (*arrow*).

The cobblestone appearance of the intestinal mucosa is the result of longitudinal and transverse ulcerations of the bowel wall. The cobblestone appearance is seen as sharply demarcated areas of high signal intensity on FISP and HASTE sequences. On thin-section images, the cobblestone appearance may also manifest as serpiginous tracks of high signal interspersed with moderate signal intensity from the edematous mucosa.

Mucosal fold thickening and irregularity—Inflammation early in the course of Crohn disease also manifests as thickening, blunting, or distortion of the valvulae conniventes. These changes can manifest as asymmetric, thickened valvulae conniventes of the affected segment. HASTE sequences may facilitate visualization of thickened folds against the high signal of luminal contrast material. Edema within the thickened folds is frequently seen as linear areas of high signal [7]. Nodular, polypoid, or asymmetric intestinal fold thickening can be a sign of early disease or of disease recurrence but may be absent in the chronic phase of Crohn disease. The presence of aphthous ulceration in combination with distorted, polypoid valvulae conniventes has high specificity for Crohn disease [11].

Intestinal hyperemia—Active inflammation is associated with mucosal hyperemia that is readily visualized on MRI after IV contrast (gadolinium) administration as intense mucosal enhancement. The peak signal intensity of mucosal enhancement has been shown to have good correlation with the Crohn disease activity index [12–14]. Occasionally hyperenhancement of the mucosa may be the only manifestation of inflammatory activity without any significant bowel thickening. This presentation is seen particularly in patients with recurrent Crohn disease because areas of fibrotic disease may not show significant bowel thickening but may display hyperenhancement of the mucosal layer.

A layered pattern of bowel enhancement is often seen in acute inflammation. This finding is also termed the "target sign." When seen *en face*, it is composed of an inner enhancing ring produced by the hyperemic mucosa, an outer ring produced by enhancing muscle and serosa, and an intermediate low-density ring produced by submucosal edema. This pattern of enhancement has been reported to have good correlation with active inflammation [15].

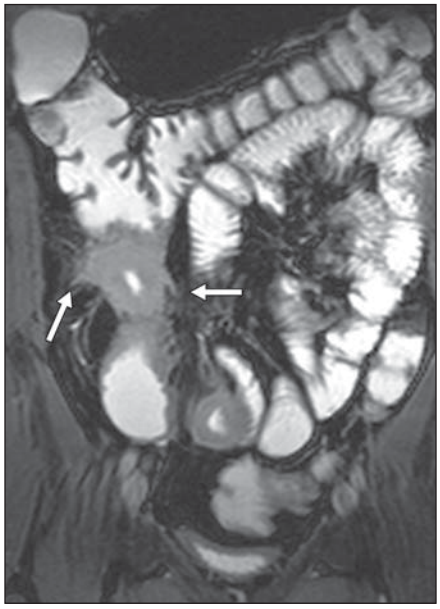


Fig. 6—42-year-old woman in treatment for known Crohn disease. Coronal true fast imaging with steady-state precession image obtained with fat saturation shows active inflammation in distal ileum. Small linear projections (*arrows*) are seen arising from bowel; these findings are indicative of incipient fistulas or sinuses.

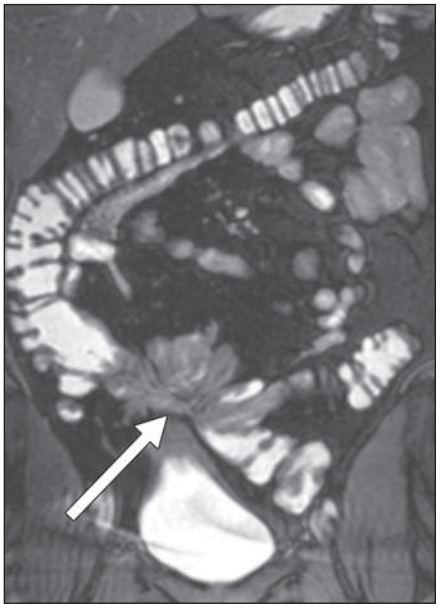


Fig. 7—32-year-old man in treatment for known Crohn disease. Coronal true fast imaging with steady-state precession image obtained with fat saturation shows ileoileal fistula (*arrow*). Note that fistula does not contain any fluid or air within patent lumen but appears isointense.

A similar target sign may be produced by a low-signal-intensity halo produced by fat hypertrophy and fibrosis of the submucosa in chronic inflammatory bowel disease. It is important to distinguish between strictures caused by spasm and active inflammation (target sign) and those caused by fibrosis (halo sign) because inflammatory strictures in active disease may be relieved by medical treatment, whereas chronic strictures may require surgical intervention.

Mesenteric changes—Distended, enhancing mesenteric vessels supplying an inflamed bowel segment produce a comb sign akin to that seen on CT examinations [16]. This sign is particularly evident on true FISP and contrast-enhanced sequences.

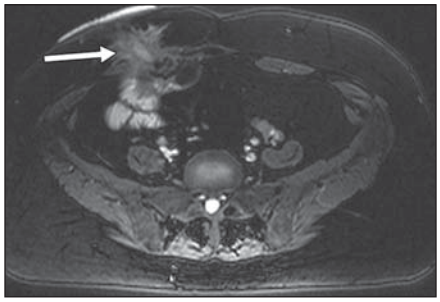
A secondary finding associated with bowel inflammation is "fat wrapping" or "fat proliferation" around the inflamed bowel [17]. This fibrofatty proliferation of the mesentery leads to increased separation of bowel loops. Mesenteric edema may also be visualized as high signal changes in the mesenteric fat surrounding the inflamed bowel, particularly on fat-suppressed sequences. Increased enhancement of the mesenteric fat around a bowel segment is a secondary sign of active bowel inflammation [18]. Fat proliferation is a distinguishing feature of Crohn disease, and its presence at MRI is indicative of the diagnosis [6].

Fistula Forming and Perforating Disease

This subtype of disease is characterized by severe inflammation with progression to transmural ulceration and fistulation (Figs. 6–8).

Fistulas occur in up to one third of patients with Crohn disease at some time during the course of the disease [19–21]. Fistulas may be external or internal, and most fistulas occur in the perineal region. The reported sensitivity value for the detection of internal fistulas ranges between 83.3% and 84.4% and the specificity is 100% [22].

Fistulas occur as a result of deep transmural ulcers or fissures that eventually penetrate the bowel muscle layer and cause inflammation in the adjacent mesenteric tissue leading to formation of small abscesses and blind-ending sinus tracts. These sinus tracts may then extend and communicate through the wall of an adjacent hollow organ and form a fistula. Incipient or early fistulas manifest as linear areas of moderate signal intensity arising from the bowel wall. These fistulas may be difficult to visualize because of partial volume averaging and the lower spatial resolution of MRI. Multiplanar imaging of the bowel is useful for a com-



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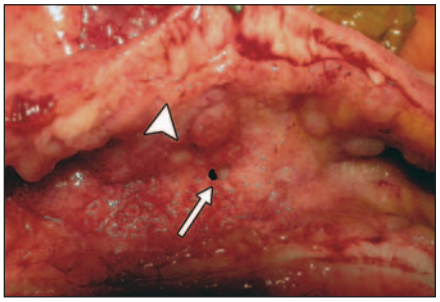

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Fig. 8—37-year-old woman with known Crohn disease and previous ileorectal anastomosis.
A, Axial true fast imaging with steady-state precession image shows large enterocutaneous fistula (*arrow*) containing high-signal enteral contrast material and surrounding inflammation.
B, Intraoperative photograph shows fistula opening in bowel wall (*arrow*) and marked mural thickening (*arrowhead*)

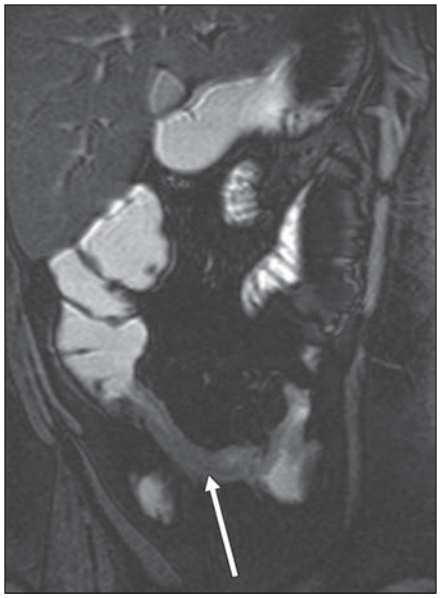

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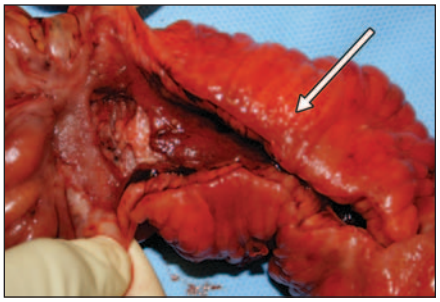
Fig. 9—33-year-old woman with known Crohn disease and previous ileocolic resection.
A, Coronal true fast imaging with steady-state precession image obtained with fat saturation shows thickened neoterminal ileum (*arrow*). Note dark submucosal band and relative lack of inflammation. This band was proven to be fibrotic stricture secondary to chronic Crohn disease.
B, Photograph of resected specimen shows fibrotic stricture (*arrow*).



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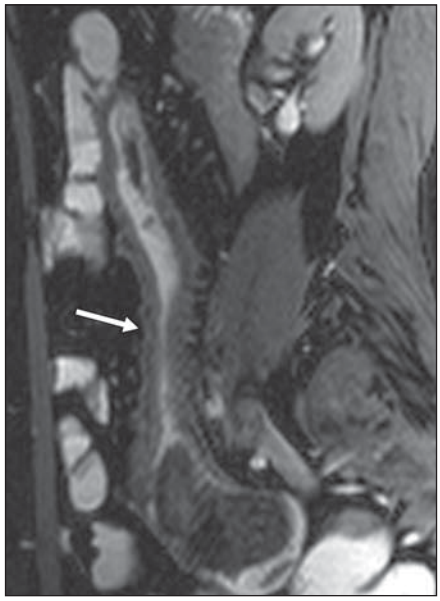

Fig. 10—57-year-old woman with known Crohn disease and previous bowel surgery. Sagittal reformatted true fast imaging with steady-state precession image obtained with fat saturation shows stricture (*arrow*). Note dark submucosal band and relative lack of inflammation. Intestinal food debris or bolus is noted proximal to obstructed segment.

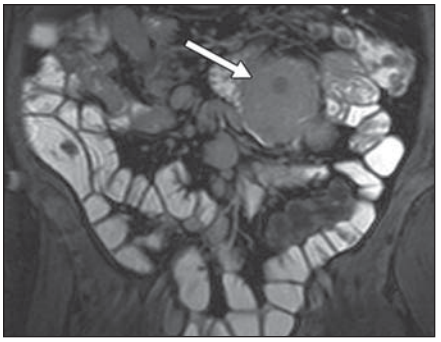

Fig. 11—71-year-old woman with known Crohn disease. Coronal true fast imaging with steady-state precession image obtained with fat saturation shows large mass arising from jejunum (*arrow*) with adjacent lymphadenopathy. Pathology results showed that mass was adenocarcinoma arising from segment affected by Crohn disease.

plete assessment and avoidance of missed sinuses. Larger sinus tracks and fistulas may be outlined by enteral contrast material as linear tracks of high signal intensity on HASTE and FISP sequences, although most fistulas are not outlined by enteral contrast [20]. Desmoplastic and fibrotic reaction in the mesentery around an inflamed fistula may create a stellate (i.e., "star") appearance. Inflamed fistulas may show avid contrast enhancement, which reflects the higher vascular flow and hyperemia in active fistulas. Extraintestinal complications such as abscesses, mesenteric inflammation, and involvement of adjacent viscera can also be associated with fistulizing disease. The detection of any intraabdominal abscess is important because the use of anti–tumor necrosis factor agents such as infliximab is contraindicated in the presence of intraabdominal abscess.

Fibrostenotic Disease

This subtype of disease is characterized by bowel obstruction (Figs. 9 and 10).

A fixed narrowing of the affected segment without any significant bowel wall thickening or inflammation is typically seen [7]. MR fluoroscopy may also show fixity of the affected segment with proximal dilatation of the bowel. Chronic fibrotic strictures are typically hypointense on both T1- and T2-weighted sequences, whereas acute inflammatory strictures due to acute inflammatory edema show the target sign. Fibrotic strictures may show minor, inhomogeneous contrast enhancement without any evidence of edema or surrounding mesenteric inflammation or hyperemia. Asymmetric bowel fibrosis and shortening secondary to ulceration of the mesenteric side of the bowel lead to the formation of pseudosacculations on the other side. These changes are well visualized on coronal images along the mesenteric plane. The ability of tissue contrast differentiation on MRI is particularly suited to distinguish between a fibrotic stricture that may require surgical intervention and an acute inflammatory stricture that may benefit from medical treatment. Obstruction is commonly caused by a single stricture, most often at the terminal ileum, that is treated by surgical resection and anastomosis [23].

Reparative or Regenerative Disease

This subtype is characterized by mucosal atrophy and the presence of regenerative polyps. Luminal narrowing may be seen, but usually there are no signs of inflammation or obstruction. Mucosal denudation with focal areas of sparing is seen on imaging. Typically, reparative polyps do not show significant hyperemia or mural edema. Extensive filiform polyposis may be seen in chronic Crohn disease as multiple filling defects extending into the lumen without an obstructive element or significant enhancement.

Complications

Segments affected by Crohn disease are at increased risk of developing adenocarcinoma, and the risk of colorectal cancer in patients with Crohn colitis is 4–20 times higher than that of the healthy population [24, 25] (Fig. 11). Furthermore, segments of bowel that are not functioning have a higher risk for developing cancer. Carcinomas usually present as stricture lesions that may be difficult to differentiate from benign fibrotic strictures. Lymphoma has been reported to present as multifocal areas of increased nodularity and strictures on barium examinations [26]. Neoplastic lesions tend to have longer strictures and may occur in noninflamed segments of bowel. Bowel cancer must be suspected when bowel obstruction in Crohn disease does not respond to conventional treatment.

Conclusion

The advantages of MRI include its high sensitivity in the diagnosis of Crohn disease and its important role in the assessment of inflammatory activity. The ability to distinguish between fibrotic and inflammatory strictures and a high sensitivity for detecting abscesses and fistulas are the other advantages that can help in guiding treatment of patients. Its nonionizing nature is also a particular advantage in patients who undergo repeated imaging investigations.

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