Small Bowel Crohn Disease at CT and MR Enterography: Imaging Atlas and Glossary of Terms

Flavius F. Guglielmo, MD
Sudha A. Anupindi, MD
Joel G. Fletcher, MD
Mahmoud M. Al-Hawary, MD
Jonathan R. Dillman, MD, MSc
David J. Grand, MD
David H. Bruining, MD
Manjil Chatterji, MD
Kassa Darge, MD, PhD
Jeff L. Fidler, MD
Namita S. Gandhi, MD
Michael S. Gee, MD, PhD
Joseph R. Grajo, MD
Chenchan Huang, MD
Tracy A. Jaffe, MD
Seong Ho Park, MD, PhD
Jordi Rimola, MD
Jorge A. Soto, MD
Bachir Taouli, MD, MHA
Stuart A. Taylor, MD
Mark E. Baker, MD

Representatives from the Society of Abdominal Radiology Crohn's Disease–Focused Panel, the Society for Pediatric Radiology, the American Gastroenterological Association, and other international experts recently reported consensus recommendations for standardized nomenclature for the interpretation and reporting of CT enterographic and MR enterographic findings of small bowel Crohn disease. The consensus recommendations included CT enterographic and MR enterographic bowel wall findings that are associated with Crohn disease, findings that occur with penetrating Crohn disease, and changes that occur in the mesentery related to Crohn disease. Also included were recommended radiology report impression statements that summarize the findings of small bowel Crohn disease at CT enterography and MR enterography. This article, authored by the Society of Abdominal Radiology Crohn's Disease–Focused Panel, illustrates the imaging findings and recommended radiology report impression statements described in the consensus recommendations with examples of CT enterographic and MR enterographic images. Additional interpretation guidelines for reporting CT enterographic and MR enterographic examinations are also presented. The recommended standardized nomenclature can be used to generate radiology report dictations that will help guide medical and surgical management for patients with small bowel Crohn disease.

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Abbreviation: ADC = apparent diffusion coefficient

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From the Department of Radiology, Thomas Jefferson University Hospital, 132 S 10th St, Philadelphia, PA 19107 (F.F.G.) The complete list of author affiliations is at the end of this article. Received March 31, 2019; revision requested May 24 and received June 23; accepted July 11. For this journal-based SA-CME activity, the authors J.R., B.T., and S.A.T. have provided disclosures (see end of article). All other authors, the editor, and the reviewers have disclosed no relevant relationships. **Address correspondence to** F.F.G. (e-mail: *flavius.guglielmo@jefferson.edu*).

SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Describe the key imaging findings of small bowel Crohn disease in the bowel wall and adjacent mesentery and imaging findings of penetrating Crohn disease at CT enterography and MR enterography.
- Implement the recommended standardized radiology report impression statements that summarize the imaging findings of small bowel Crohn disease.
- Discuss additional interpretation guidelines used when reporting small bowel Crohn disease at CT enterography and MR enterography.

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Introduction

CT enterography and MR enterography have become widely accepted methods for performing detailed evaluation of the small bowel in patients with Crohn disease (1–3). Both CT enterography and MR enterography can help identify disease involvement, activity, and extent, along with the presence of complications. Both techniques can also help evaluate response to medical treatment or progression of disease at follow-up examinations (4–6). For radiologists interpreting these images, it is important to recognize the key imaging findings in

TEACHING POINTS

- A *stricture* is defined as a bowel segment with luminal narrowing and unequivocal dilation (ie, ≥ 3 cm) of the upstream bowel segment. *Luminal narrowing* is defined as luminal diameter reduction of at least 50% compared with that of a normal adjacent bowel loop.
- There is increasing evidence of an association between stricture formation and penetrating disease in the small bowel. Therefore, when penetrating disease such as a fistula or inflammatory mass manifests, it is important to evaluate for an adjacent strictured bowel segment, which is usually associated with active inflammation. Conversely, if a stricture with active inflammation is present, it is important to evaluate for associated penetrating disease such as a fistula, which usually arises in the mid or proximal aspect of a stricture.
- The impression statement "nonspecific small bowel inflammation" describes bowel loops that have segmental symmetric mural hyperenhancement and/or wall thickening in a patient without a proven Crohn disease diagnosis. Many entities besides Crohn disease can cause this appearance. Only the location and length of the nonspecific small bowel inflammation should be reported.
- It is appropriate to indicate that inflammatory small bowel Crohn disease is likely when mural hyperenhancement and wall thickening are present and the patient has a history of Crohn disease.
- It is also appropriate to indicate that inflammatory small bowel Crohn disease is likely when small bowel inflammation is asymmetric (more severe along the mesenteric border of the bowel) or if bowel inflammation coexists with penetrating complications typical of Crohn disease (after excluding other causes of penetrating complications such as appendicitis, diverticulitis, neoplasm, or tuberculosis), even if there is no known history of Crohn disease.

Crohn disease and understand how to synthesize these imaging findings to generate standardized, clear, and clinically useful radiology reports.

In a recent special report published jointly in the journals *Radiology* and *Gastroenterology* (7,8), representatives from the Society of Abdominal Radiology Crohn's Disease–Focused Panel, the Society for Pediatric Radiology, the American Gastroenterological Association, and other international experts agreed on consensus recommendations for standardized nomenclature for interpreting and reporting imaging findings at CT enterography and MR enterography in patients with small bowel Crohn disease, including the bowel wall imaging findings associated with small bowel Crohn disease, imaging findings of penetrating Crohn disease, and changes that occur in the mesentery related to Crohn disease. This standardized nomenclature can be used to generate standardized radiology report impression statements that clinicians can rely on when formulating treatment and follow-up plans. In this pictorial article, authored by the Society of Abdominal Radiology Crohn's Disease–Focused Panel, many of the Crohn disease bowel wall and mesenteric imaging findings and imaging findings of penetrating Crohn disease described in the consensus recommendations (7,8) are illustrated with examples using CT enterographic or MR enterographic images (Tables 1–3). Also demonstrated are examples of the agreed-on recommended standardized radiology report impression statements to use when reporting findings at CT enterographic and MR enterographic examinations in patients with small bowel Crohn disease (Table 4). Finally, additional interpretation guidelines for reporting these examinations are presented.

Bowel Wall Imaging Findings Associated with Small Bowel Crohn Disease Inflammation

Segmental Mural Hyperenhancement

Segmental mural hyperenhancement is defined as increased mural attenuation at CT enterography or increased mural signal intensity at MR enterography on contrast material–enhanced images in a noncontracted small bowel segment compared with that of adjacent normal small bowel segments (9–13). Mural hyperenhancement can be asymmetric, stratified, or homogeneous in appearance.

Bowel wall enhancement is ideally evaluated in the enteric phase (45–50 seconds after the intravenous contrast material injection begins) and/or portal venous phase (60–70 seconds after the intravenous contrast material injection begins) (14–17). While there may be more bowel wall enhancement during the enteric phase, a study by Vandenbroucke et al (18) showed no difference in lesion detection in Crohn disease between the enteric and portal venous phases (16,18,19).

Asymmetric Mural Hyperenhancement.—Asymmetric mural hyperenhancement (Fig 1) is a specific imaging finding for small bowel Crohn disease and often involves the mesenteric border of a small bowel loop more than the antimesenteric border (20,21).

Stratified Mural Hyperenhancement.—*Stratified mural hyperenhancement* (Fig 2) is defined as hyperenhancement of the inner (bilaminar) or both the inner and outer (trilaminar) aspects of the bowel wall (22). In patients with Crohn disease, stratified enhancement can be due to a combination of submucosal edema, granulation tissue, intramural fat deposition, fibrosis, or inflammatory infiltration (23). The term *mucosal hyperenhancement* should not be used when the stratified enhancement pattern is depicted because the mucosa of inflamed bowel segments is commonly absent at endoscopy and histopathologic analysis.

Table 1. Bowel Wall Imaging Findings Associated with Small Bowel Crohn Disease Inflammation

Segmental mural hyperenhancement
Asymmetric
Stratified (bilaminar or trilaminar)
Homogeneous, symmetric
Wall thickening
Mild (3–5 mm)
Moderate (>5–9 mm)
Severe (≥10 mm)
Intramural edema
Stricture
Probable stricture without upstream dilation (<3 cm)*
Stricture with mild upstream dilation (3–4 cm)
Stricture with moderate to severe upstream dilation (>4 cm)
Ulcerations
Restricted diffusion
Sacculations†
Diminished motility

Note.—Adapted, with permission, from references 7 and 8.
*A *stricture* is defined as a bowel segment that has luminal narrowing and unequivocal upstream bowel dilation. However, there are several scenarios in which a stricture may be present without upstream dilation, as described in the "Probable Stricture without Upstream Dilation (<3 cm)" section.
†Sacculations are sequelae of current or prior inflammation but do not reflect inflammation as an isolated imaging finding.

Table 2: Imaging Findings of Penetrating Crohn Disease

Sinus tract
Fistula
Simple fistula
Complex fistula
Inflammatory mass
Abscess
Free perforation

Note.—Adapted, with permission, from references 7 and 8.

Table 3: Mesenteric Findings Associated with Small Bowel Crohn Disease

Perienteric edema and/or inflammation
Engorged vasa recta
Fibrofatty proliferation
Mesenteric venous thrombosis and/or occlusion
Lymphadenopathy

Note.—Adapted, with permission, from references 7 and 8.

Trilaminar enhancement is more often identified with MR enterography than with CT enterography, probably owing to the superior contrast resolution at MR enterography.

Homogeneous Symmetric Mural Hyperenhancement.—Homogeneous symmetric mural hyperenhancement (Fig 3) is transmural hyperenhancement that uniformly involves the entire bowel wall and can have many other causes besides Crohn disease, including fibrosis, infiltration, ischemia, collagen deposition, or shock bowel (12,24–27).

Wall Thickening

Wall thickness should be evaluated and measured in a bowel segment that is adequately distended by fluid or enteric contrast material (28). The thickest portion of the most distended segment or the site of the most severe inflammation should be measured. Wall thickening should be subdivided as mild (3–5 mm) (Fig 4), moderate (>5–9 mm) (Fig 5), or severe (≥10 mm) (Fig 6) (29–33). Bowel wall thickening greater than 15 mm is atypical for Crohn disease and should raise suspicion for neoplasm, especially if the thickening is asymmetric or masslike (34–36).

Intramural Edema

Intramural edema (Figs 6, 7), also known as mural edema, is identified when hyperintense signal in the bowel wall is present on fat-suppressed T2-weighted images or low *b*-value (ie, a *b* value of 0–20 sec/mm^2) diffusion-weighted images (29,37). High signal intensity on non–fat-suppressed T2-weighted images can also represent intramural fat but can be differentiated from edema when it loses signal intensity with fat-suppressed sequences. Intramural fat can be caused by prior bowel inflammation. Intramural edema cannot be as well evaluated with CT enterography owing to lower contrast resolution compared with that of MRI (38).

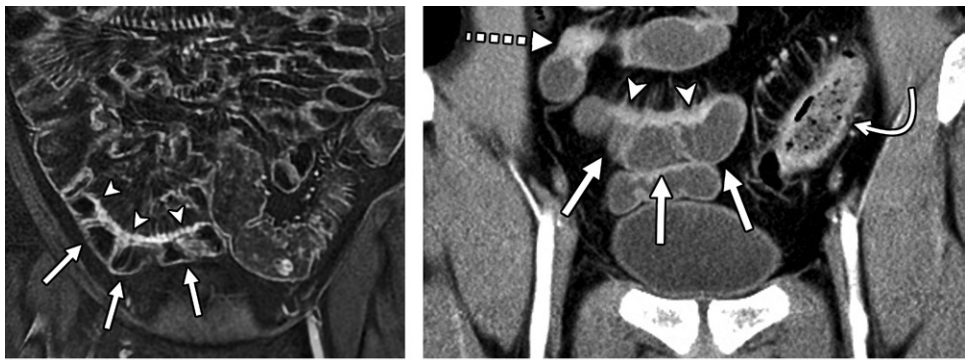
Stricture

A *stricture* is defined as a bowel segment with luminal narrowing and unequivocal dilation (ie, ≥3 cm) of the upstream bowel segment (39–42). *Luminal narrowing* is defined as luminal diameter reduction of at least 50% compared with that of a normal adjacent bowel loop (42). A stricture can be present with or without active inflammation. However, studies have shown that most strictures

Table 4. Recommended Radiology Report Impression Statements for Small Bowel Crohn Disease at CT Enterography and MR Enterography

Inflammation impression statements
No imaging signs of active inflammation
Nonspecific small bowel inflammation
Active inflammatory small bowel Crohn disease without luminal narrowing
Active inflammatory small bowel Crohn disease with luminal narrowing
Crohn disease with no imaging signs of active inflammation
Stricture impression statements
Stricture with imaging findings of active inflammation
Stricture without imaging findings of active inflammation
Penetrating Crohn disease impression statements
Sinus tract
Fistula
Inflammatory mass
Abscess
Free perforation
Perianal Crohn disease impression statements
Fistula
Abscess
Other complications impression statements
Femoral head avascular necrosis, sacroiliitis, primary sclerosing cholangitis, pancreatitis, mesenteric venous thrombosis or chronic mesenteric venous occlusion, neoplasm, cholelithiasis, or nephrolithiasis

Note.—Adapted, with permission, from references 7 and 8.

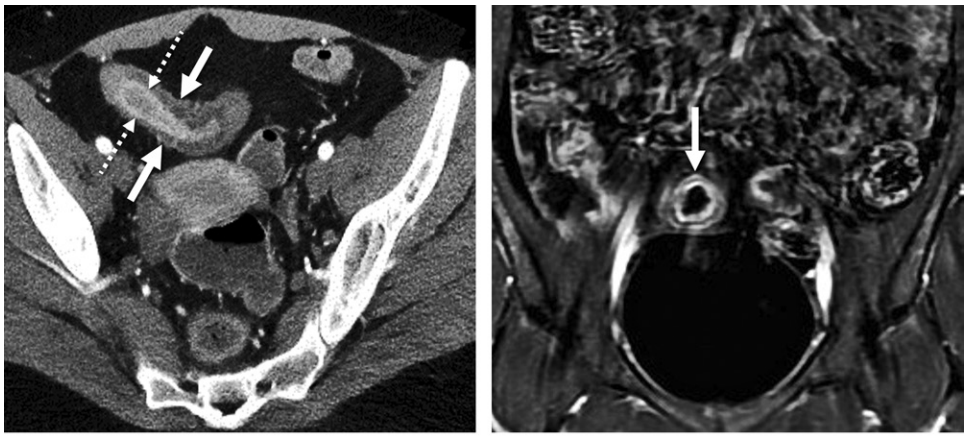


a. **b.**

Figure 1. Asymmetric mural hyperenhancement in two patients with Crohn disease. Coronal contrast-enhanced fat-suppressed T1-weighted MR enterographic image with biphasic oral contrast material **(a)** and coronal contrast-enhanced CT enterographic image with neutral oral contrast material **(b)** show asymmetric bowel wall thickening and hyperenhancement along the mesenteric side (arrowheads), with relative sparing of the antimesenteric side (solid straight arrows) of the ileum, findings consistent with active inflammation secondary to Crohn disease. As a result, there is effacement of the folds along the mesenteric border and sacculations along the antimesenteric border. Note the engorged vasa recta adjacent to the mesenteric border in both images. The CT image **(b)** also shows active inflammation with luminal narrowing in a different small bowel loop (dashed arrow in **b**) and inflammation of the distal colon (curved arrow in **b**).

will have a component of active inflammation and that histologic fibrosis and inflammation are usually positively correlated (39,40,43,44). Strictured bowel segments often show evidence of smooth muscle hypertrophy at histopathologic examination, although the wall can also be thickened by inflammatory cell infiltration, as well as fibrosis (45). When a stricture is present, the location and length of the stricture and imaging findings of concurrent inflammation or upstream dilation should be reported (7,8). If the stricture is associated with an enteric anastomosis, this should be mentioned, because the cause and response to endoscopic therapy of the anastomotic strictures may be different compared with those of native small bowel Crohn disease strictures (46).

There is increasing evidence of an association between stricture formation and penetrating dis-



a. b.

Figure 2. Stratified (bilaminar or trilaminar) mural hyperenhancement. **(a)** Axial contrast-enhanced CT enterographic image with neutral oral contrast material shows stratified (bilaminar) mural hyperenhancement with small bowel wall thickening (solid arrows), hyperenhancement of the inner aspect of the bowel wall (dashed arrows), and luminal narrowing, findings consistent with active inflammatory Crohn disease with luminal narrowing. **(b)** Coronal contrast-enhanced fat-suppressed T1-weighted MR enterographic image with biphasic oral contrast material in a different patient shows small bowel wall thickening with stratified (trilaminar) mural hyperenhancement (arrow), findings consistent with active inflammatory Crohn disease.

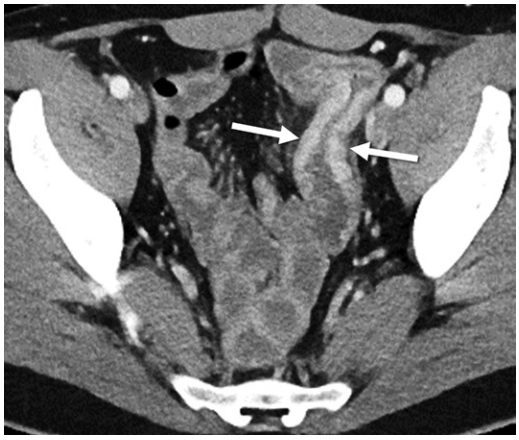


Figure 3. Homogeneous symmetric mural hyperenhancement. Axial contrast-enhanced CT enterographic image with neutral oral contrast material in a patient with Crohn disease shows moderate small bowel wall thickening with homogeneous symmetric bowel wall hyperenhancement (arrows) and luminal narrowing, findings consistent with active inflammatory Crohn disease with luminal narrowing.

ease in the small bowel (47–49). Therefore, when penetrating disease such as a fistula or inflammatory mass manifests, it is important to evaluate for an adjacent strictured bowel segment, which is usually associated with active inflammation. Conversely, if a stricture with active inflammation is present, it is important to evaluate for associated penetrating disease such as a fistula, which usually arises in the mid or proximal aspect of a stricture (47–49).

Probable Stricture without Upstream Dilation (<3 cm).—There are several scenarios in which a stricture may be present without upstream dilation (ie, <3 cm). For example, if a fistula or other penetrating complication develops adjacent to a stricture with active inflammation, this may decompress the upstream small bowel segment, resulting in no upstream dilation (47,48) (Fig 8). In this case, the radiology report impression statement can state "active inflammatory small bowel Crohn disease with luminal narrowing associated with penetrating disease; stricture with imaging signs of active inflammation is highly likely."

Another possible scenario is if there are two or more strictures in close proximity, in which case the distal stricture may not have associated upstream dilation because of the impeded inflow of bowel contents from the more proximal stricture. Finally, if there is fixed luminal narrowing without overt upstream dilation with multiple MR pulse sequences or at serial imaging examinations, the report impression can indicate that a "probable stricture without upstream dilation" is present.

Stricture with Mild Upstream Dilation (3–4 cm).—When a stricture is present, most commonly there will be mild (3–4 cm) dilation of the upstream bowel segment. Small bowel debris or fecalization (ie, the small bowel feces sign) may also be depicted in the more proximal small bowel, given the long-standing nature of these strictures (Fig 9).

Stricture with Moderate to Severe Upstream Dilation (>4 cm).—If there is moderate to severe upstream dilation (>4 cm) associated with a stricture, it may be appropriate to use the phrase

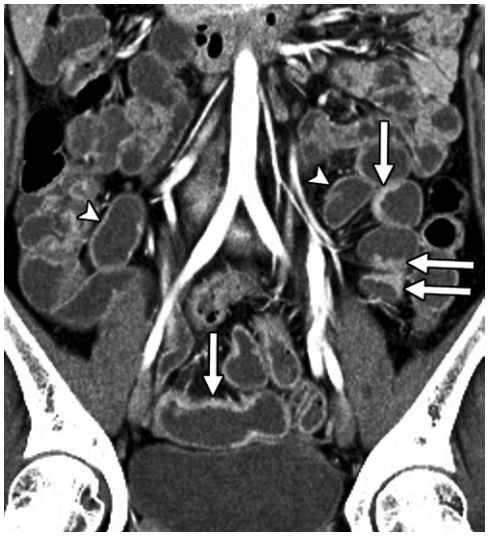


Figure 4. Mild wall thickening (3–5 mm). Coronal contrast-enhanced CT enterographic image with neutral oral contrast material shows mild bowel wall thickening, with asymmetric mural hyperenhancement along the mesenteric border in several small bowel segments (arrows), compared with normal thickness in the uninvolved segments (arrowheads). These findings are consistent with active inflammatory small bowel Crohn disease.

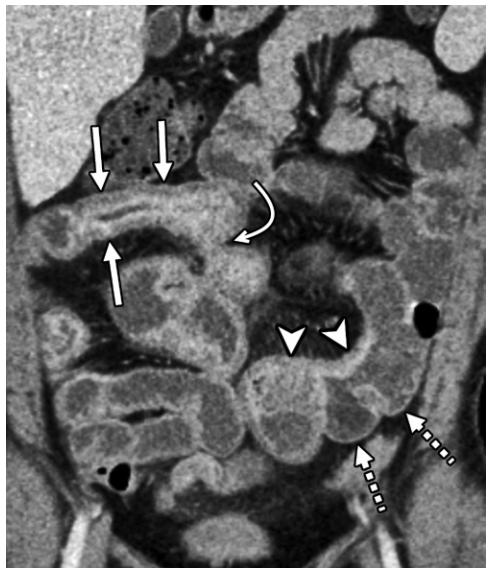


Figure 5. Moderate wall thickening (>5–9 mm). Coronal contrast-enhanced CT enterographic image with neutral oral contrast material shows moderate small bowel wall thickening with stratified mural hyperenhancement and luminal narrowing (solid straight arrows), consistent with active inflammatory Crohn disease with luminal narrowing. There is an enteroenteric fistula (curved arrow) at the proximal end of this bowel segment. In a different small bowel segment, there are sacculations (dashed arrows) along the antimesenteric border caused by asymmetric bowel wall inflammation (arrowheads) along the mesenteric wall.

"with small bowel obstruction" in the radiology report impression statement (Fig 10).

Ulcerations

An *ulceration* is defined as a break in the intraluminal surface of the bowel wall, with extension of intraluminal contents (eg, oral contrast material) into the bowel wall (5,30,50–52) (Fig 11). The term *penetrating ulcer* should not be used, to avoid confusion with penetrating disease (eg, a sinus tract, fistula, or abscess) or cardiovascular pathologic disease. Furthermore, by definition, an *ulcer* is a defect that is confined to the bowel wall. This is in contrast to a sinus tract, which is a defect in the bowel wall that extends through the serosa into the mesenteric fat.

Restricted Diffusion

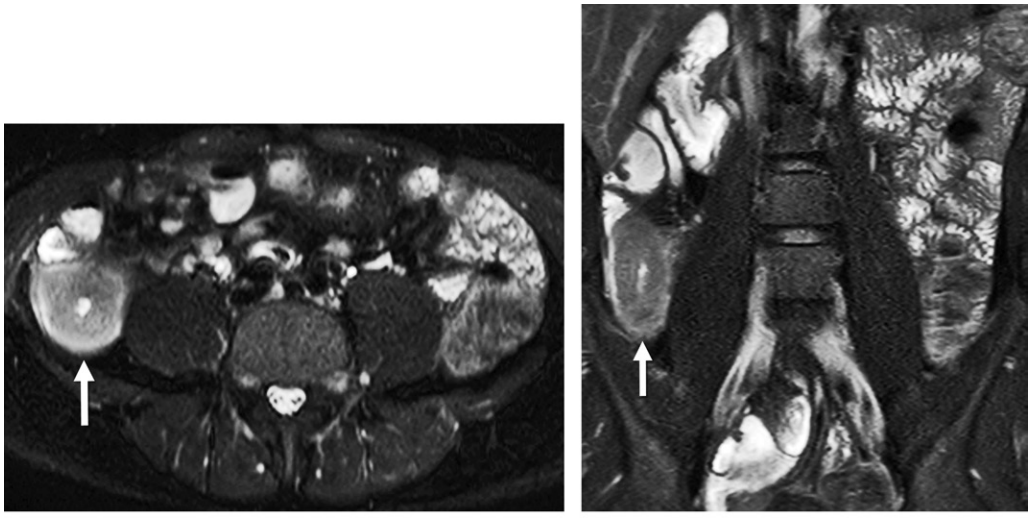
Active inflammation in Crohn disease has been shown to restrict diffusion of water molecules in the bowel wall (Fig 12). Bowel segments with restricted diffusion have high signal intensity on high *b*-value diffusion-weighted images (ie, *b* value of at least 500 sec/mm^2) and low signal intensity on corresponding apparent diffusion coefficient (ADC) maps (53–55). However, restricted diffusion is a nonspecific sign. Therefore, findings of mural inflammation should be depicted on conventional contrast-enhanced T1-weighted and/or fat-suppressed T2-weighted MR images before attributing restricted diffusion to Crohn disease active inflammation (53,56). Radiologists should also be aware that bowel segments may demonstrate spurious high signal intensity on diffusion-weighted images when inadequately distended, especially in the jejunum and large bowel (53,57–60).

Sacculations

Sacculations (also known as pseudosacculations) are broad-based outpouchings along the antimesenteric border of a bowel loop and result from shortening along the mesenteric border owing to either acute or long-standing bowel wall inflammation and/or fibrosis (20,21,61,62) (Fig 13).

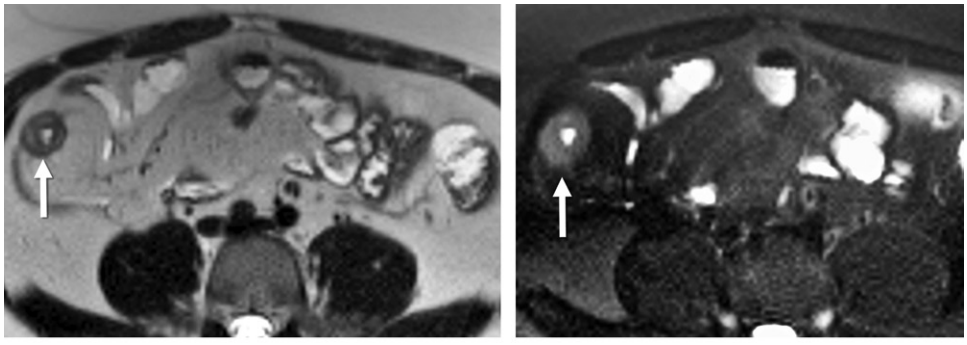
Diminished Motility

While conventional T1- and T2-weighted images, supplemented with diffusion-weighted images, are the primary MRI sequences used for diagnosing and determining the severity of bowel inflammation, cine MRI performed without the use of antiperistaltic agents can identify decreased bowel motility and thereby improve confidence in diagnosing bowel inflammation or a stricture (Movie 1) (63–66). Similarly, normal small bowel motility seen with cine MR enterographic pulse sequences is reassuring that MR enterographic findings are normal (Movie 2). This is particularly



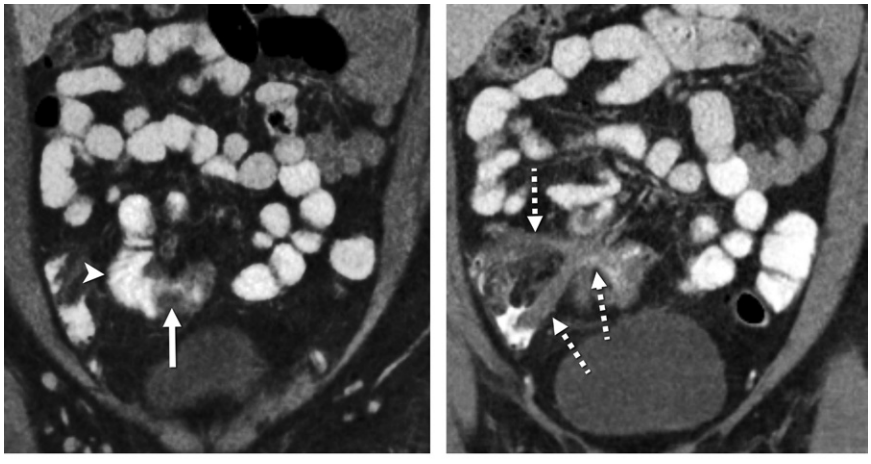
a. b.

Figure 6. Severe wall thickening (≥10 mm). Axial **(a)** and coronal **(b)** fat-suppressed T2-weighted MR enterographic images with biphasic oral contrast material show severe small bowel wall thickening, mural edema (hyperintense mural signal intensity compared with that of the adjacent psoas muscle or normal bowel wall), luminal narrowing, and perienteric edema, findings consistent with active inflammatory Crohn disease with luminal narrowing (arrow).



a. b.

Figure 7. Intramural edema. Axial T2-weighted MR enterographic images with biphasic oral contrast material without **(a)** and with **(b)** fat suppression in a patient with Crohn disease show bowel wall thickening in the distal ileum, with increased mural signal intensity (arrow in **a**). On the fat-suppressed T2-weighted image, there is persistent increased signal intensity in the thickened bowel wall (arrow in **b**). This finding confirms that edema accounts for the high signal intensity rather than fat, which would have lost signal intensity with this sequence.



a. b.

Figure 8. Probable stricture without upstream dilation (<3 cm). Coronal contrast-enhanced CT enterographic images with positive oral contrast material in a patient with Crohn disease show a probable stricture without upstream dilation. In **a**, there is a probable stricture with small bowel wall thickening and luminal narrowing (solid arrow) without upstream dilation (arrowhead). In **b**, arising from the probable stricture, there are multiple enteroenteric and enterocolic fistulas (dashed arrows) causing an asterisk appearance (or star sign) in the small bowel mesentery, likely decompressing the nondilated upstream small bowel segment.

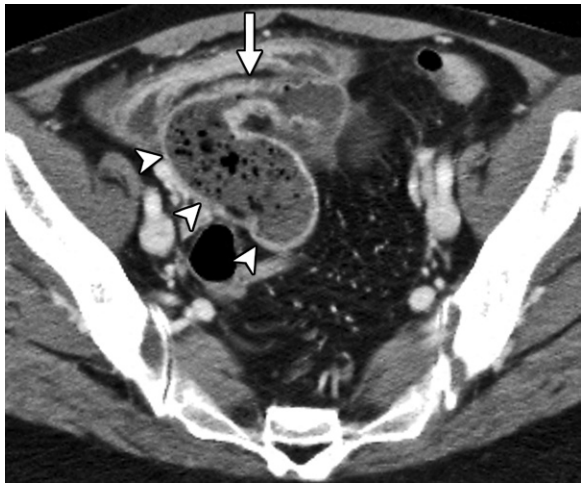
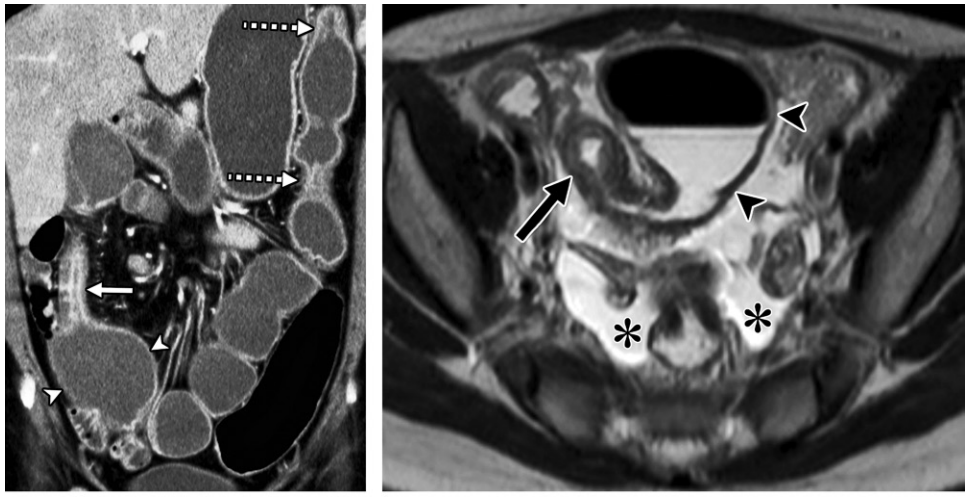


Figure 9. Stricture with mild upstream dilation (3–4 cm). Axial contrast-enhanced CT enterographic image with neutral oral contrast material in a patient with Crohn disease shows a short segment stricture with active inflammation in the ileum (arrow), with mild upstream bowel dilation in addition to the small bowel feces sign (arrowheads) in the dilated segment.



a. **b.**

Figure 10. Stricture with moderate to severe upstream dilation (>4 cm) in two patients with Crohn disease. **(a)** Coronal contrast-enhanced CT enterographic image with neutral oral contrast material shows wall thickening in the distal ileum (solid arrow) with stratified mural hyperenhancement, luminal narrowing, and moderate to severe upstream dilation (arrowheads), findings consistent with a stricture with active inflammation. There are two additional jejunal strictures (dashed arrows) with active inflammation in the left upper quadrant. **(b)** Axial T2-weighted MR enterographic image with biphasic oral contrast material shows wall thickening, mural edema, and luminal narrowing in the distal ileum (arrow), with moderate to severe upstream dilation (arrowheads), findings consistent with a stricture with active inflammation associated with free fluid in the pelvis (*).

helpful when performing MR enterography in symptomatic patients who can only ingest a small volume of enteric contrast material, to distinguish underdistended from inflamed bowel. One study showed that reduction in segmental bowel motility correlates with the severity of underlying inflammation (66).

Imaging Findings of Penetrating Crohn Disease

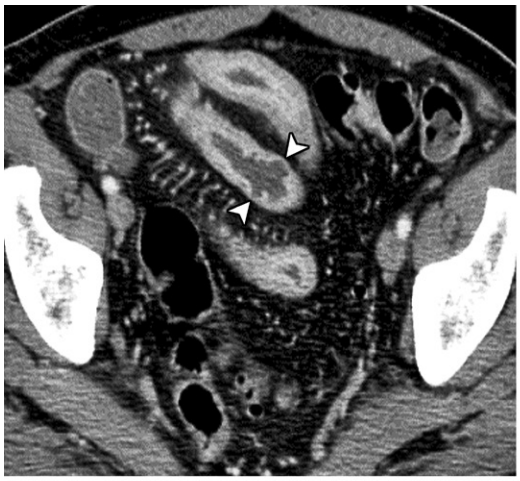
Sinus Tract

A *sinus tract* is defined as a blind-ending tract that extends beyond the bowel wall serosa but does not reach adjacent organs or the skin (Fig 14).

Simple and Complex Fistulas

A *simple fistula* (Fig 14) is defined as a single extraenteric tract, which may or may not contain fluid, that connects the bowel lumen to another epithelialized surface (47,48,67). Fistulas usually arise from the mid or proximal aspect of a stricture and usually occur in the setting of a stricture with active inflammation (47–49). Simple fistulas are named by the structures that they connect, such as an enteroenteric, enterocolic, enterovesical, enterocutaneous, or rectovaginal fistula (68).

A *complex fistula* is defined as the presence of more than one fistulous tract and can result in an asterisk-shaped or cloverleaf appearance



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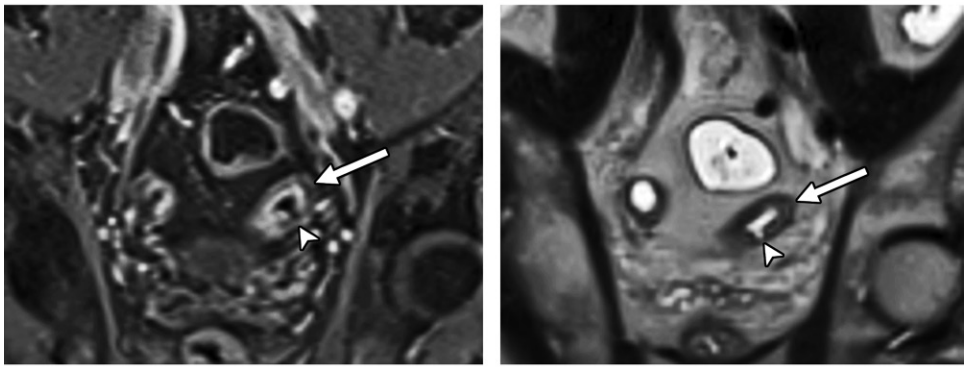
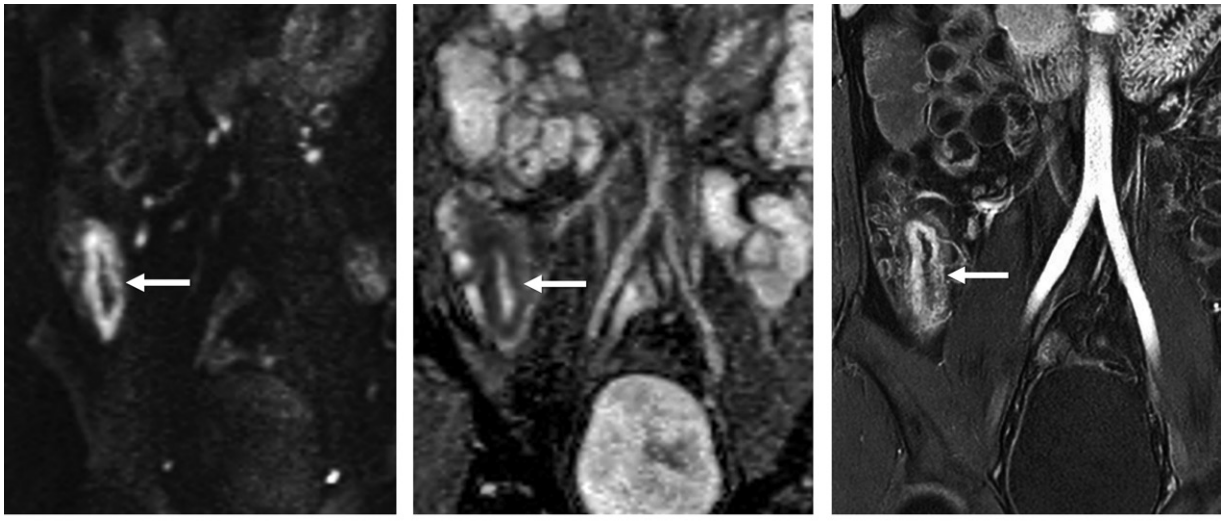


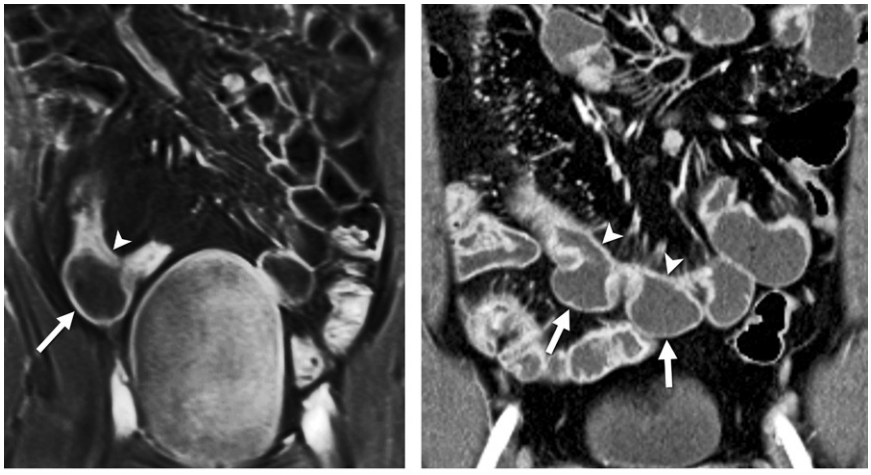
b. c.

Figure 11. Ulcerations in two patients. **(a)** Axial contrast-enhanced CT enterographic image with neutral oral contrast material shows a small bowel segment with bowel wall thickening, stratified mural hyperenhancement, luminal ulcerations (arrowheads), and adjacent engorged mesenteric vessels, findings consistent with active inflammatory Crohn disease. **(b, c)** Coronal contrast-enhanced fat-suppressed T1-weighted **(b)** and T2-weighted **(c)** MR enterographic images with biphasic oral contrast material in a different patient show small bowel wall thickening (arrow), stratified mural hyperenhancement in **b**, and an intramural ulcer (arrowhead), findings consistent with active inflammatory Crohn disease.



a. b. c.

Figure 12. Restricted diffusion. Coronal diffusion-weighted image (b = 900 sec/mm^2) **(a)**, ADC map **(b)**, and contrast-enhanced fat-suppressed T1-weighted **(c)** MR enterographic images with biphasic oral contrast material in a patient with Crohn disease show marked bowel wall diffusion restriction in the terminal ileum, manifesting as hyperintense signal (arrow in **a**) on the diffusion-weighted image and hypointense signal (arrow in **b**) on the ADC map. The same segment has moderate wall thickening and stratified mural hyperenhancement (arrow in **c**) on the contrast-enhanced fat-suppressed T1-weighted image.



a. b.

Figure 13. Sacculations in two patients with Crohn disease. **(a)** Coronal contrast-enhanced fat-suppressed T1-weighted MR enterographic image with biphasic oral contrast material shows asymmetric wall thickening involving the mesenteric wall of a small bowel segment (arrowhead) and a sacculation on the antimesenteric wall (arrow). **(b)** Coronal contrast-enhanced CT enterographic image with neutral oral contrast material shows several sacculations along the antimesenteric wall (arrows) of a small bowel segment and asymmetric inflammation along the mesenteric wall (arrowheads).

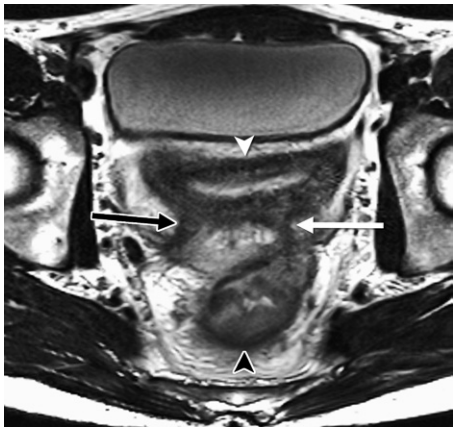


Figure 14. Sinus tract and simple fistula. Axial T2-weighted MR enterographic image with biphasic oral contrast material shows severe small bowel wall thickening and bowel wall edema in the ileum (white arrowhead) and rectosigmoid colon (black arrowhead), findings consistent with active inflammatory Crohn disease with an associated enterocolic fistula (white arrow) and a blind-ending sinus tract (black arrow) arising from the ileum.

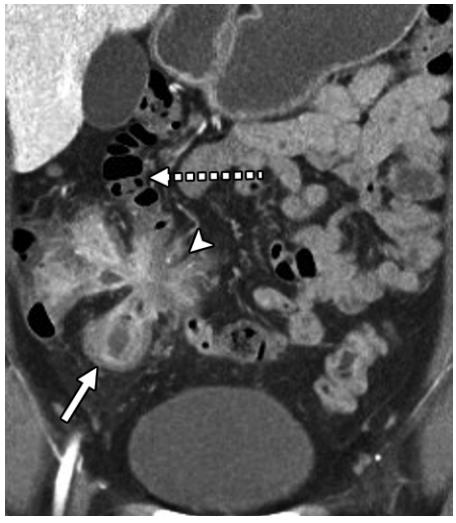
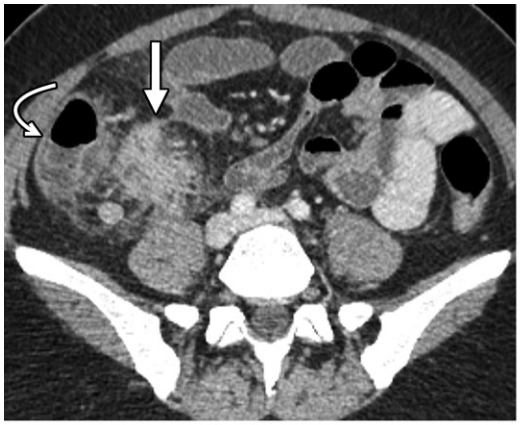


Figure 15. Complex fistula. Coronal contrast-enhanced CT enterographic image with neutral oral contrast material shows a thick-walled small bowel segment with hyperenhancement in the right lower quadrant (solid arrow), consistent with active inflammatory Crohn disease. There are multiple associated enteroenteric fistulas extending into the adjacent mesentery with tethering, leading to multiple small bowel loops with an asterisk appearance (arrowhead). An enterocolic fistula to the adjacent transverse colon (dashed arrow) is also present.

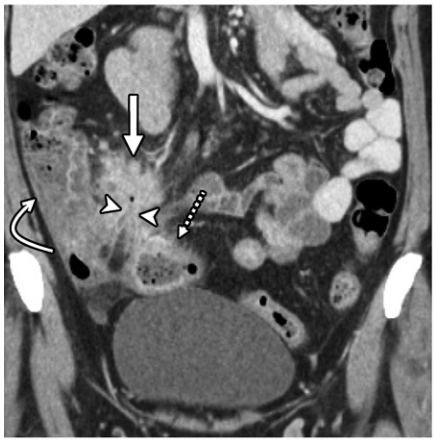
of the small bowel (sometimes called the star sign) owing to the angulation and tethering of the affected bowel loops (Figs 8, 15) (7,8,69). Other penetrating complications, such as an inflammatory mass (Fig 16) or interloop abscess (Fig 17), may also manifest.

Inflammatory Mass

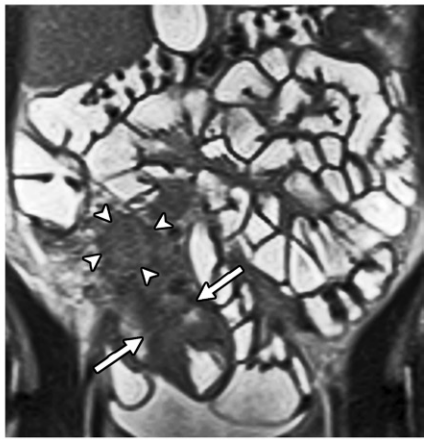
An *inflammatory mass* (Fig 16) is defined as dense mesenteric inflammation without a well-defined fluid component or discrete wall, which occurs adjacent to a bowel segment that has mural inflammation (41). An inflammatory mass is generally composed of ill-defined soft-tissue attenuation on CT enterographic images or variable signal intensity on MR enterographic images, mixed with fat. The term *phlegmon* is ambiguous and thus should not be used to describe an inflammatory mass.



a.



b.



c.

Figure 16. Inflammatory mass in two patients with Crohn disease. **(a, b)** Axial **(a)** and coronal **(b)** contrast-enhanced CT enterographic images with positive oral contrast material in the same patient show bowel wall thickening and stratified mural hyperenhancement involving the terminal ileum (dashed arrow in **b**) and ascending colon (curved arrow). There is an adjacent enhancing mesenteric inflammatory mass (solid straight arrow) with sinus tracts that extend from the terminal ileum and ascending colon (arrowheads in **b**). **(c)** Coronal T2-weighted MR enterographic image with biphasic oral contrast material in a different patient shows a large hypointense mesenteric inflammatory mass (arrowheads) adjacent to a thick-walled small bowel segment (arrows).

Abscess

An abscess (Fig 17) is a fluid collection with rim enhancement on contrast-enhanced CT enterographic or MR enterographic images owing to the presence of a well-formed wall, with or without internal gas. On diffusion-weighted images, abscesses usually have restricted diffusion with high signal intensity on high *b*-value images (ie, a *b* value of at least 500 sec/mm^2) and low signal intensity on corresponding ADC maps. Performing diffusion-weighted imaging is especially important in patients with a contraindication to intravenous contrast material (70). Abscesses can occur in the mesentery, peritoneal cavity, retroperitoneum, body wall, or perirectal and/or perianal region.

Free Perforation

Rarely, penetrating Crohn disease can lead to free perforation with free intraperitoneal air, requiring surgical evaluation.

Mesenteric Findings Associated with Small Bowel Crohn Disease

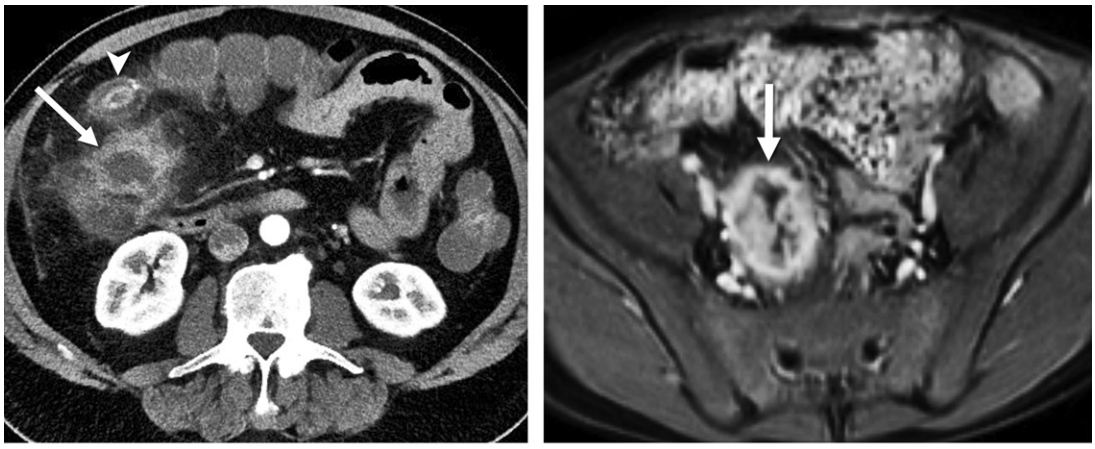
Perienteric Edema and/or Inflammation

Perienteric edema and/or inflammation (Fig 18) manifests as increased attenuation on CT enterographic images, or increased T2-weighted signal intensity on MR enterographic images, in the mesenteric fat adjacent to the diseased bowel loops. Perienteric inflammation often represents extension of transmural bowel wall inflammation (71).

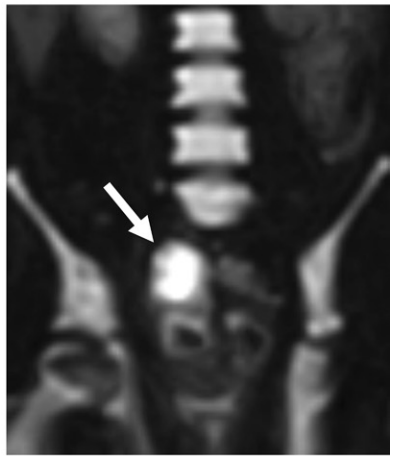
Engorged Vasa Recta

Engorged vasa recta (Fig 19) are defined as enlarged blood vessels that supply and drain an inflamed bowel loop. The presence of engorged vasa recta is known as the comb sign and can occur when there is either current or previous bowel inflammation (71,72).

Figure 17. Abscess in two patients with Crohn disease. **(a)** Axial contrast-enhanced CT enterographic image with neutral oral contrast material shows a right lower quadrant mesenteric fluid collection with rim enhancement and adjacent inflammation, consistent with an abscess (arrow) adjacent to a thick-walled small bowel segment, with stratified mural hyperenhancement and luminal narrowing (arrowhead). **(b, c)** Axial contrast-enhanced fat-suppressed T1-weighted **(b)** and coronal diffusion-weighted (b = 800 sec/mm^2) **(c)** MR enterographic images with biphasic oral contrast material in a different patient show a rim-enhancing collection containing T1-hyperintense debris (arrow in **b**), consistent with an abscess, with high signal intensity (arrow in **c**) on the diffusion-weighted image owing to restricted diffusion.



a. **b.**



c.

Fibrofatty Proliferation

Fibrofatty proliferation (sometimes called creeping fat) refers to hypertrophy of the mesenteric fat adjacent to diseased bowel segments, which displaces surrounding structures (37,73) (Fig 20). With fibrofatty proliferation, the hypertrophied mesenteric fat may show slightly increased attenuation on CT enterographic images and slightly decreased signal intensity on T1-weighted MR enterographic images compared with that of normal fat owing to an influx of inflammatory cells and fluid (72,74–79). Typically, it occurs along the mesenteric border, but it can also be circumferential (72).

Mesenteric Venous Thrombosis and/or Occlusion

Mesenteric venous thrombosis and/or occlusion (Fig 21) generally occurs adjacent to inflamed bowel segments (80). When acute, intraluminal thrombus typically distends the vein. When chronic, the central mesenteric veins may be narrowed or interrupted, resulting in distended collateral mesenteric vessels and/or small bowel varices (81). If acute thrombus is absent, the phrase "chronic mesenteric venous occlusion" is more appropriate to use than "mesenteric venous thrombosis" to avoid confusion about the need to administer anticoagulation therapy.

Lymphadenopathy

Mesenteric lymph nodes are measured in the short axis. Enlarged mesenteric lymph nodes up to 1–1.5 cm in short-axis diameter are common in Crohn disease and are usually reactive in etiology.

Recommended Radiology Report Impression Statements

The following sections describe recommended radiology report impression statements for findings of inflammation, strictures, penetrating and perianal Crohn disease, and other complications. We have created a structured report template to accompany this article. This template is available at *https://radreport.org/home/50799*.

Inflammation Impression Statements

No Imaging Signs of Active Inflammation.—The impression statement "no imaging signs of active inflammation" should be used when no findings of small bowel inflammation or bowel wall thickening are present (Fig 22). This impression can be used for CT enterographic and MR enterographic examinations in which Crohn disease is

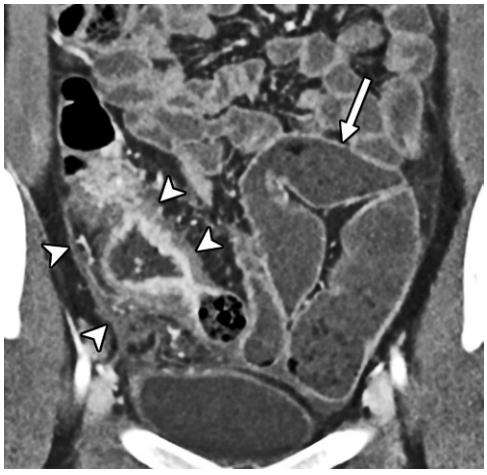


Figure 18. Perienteric edema and/or inflammation. Coronal contrast-enhanced CT enterographic image with neutral oral contrast material in a patient with Crohn disease shows perienteric edema and trace fluid (arrowheads), adjacent to a thick-walled small bowel segment, with stratified mural hyperenhancement. There is also upstream small bowel dilation (arrow). The findings are consistent with a stricture with active inflammation.

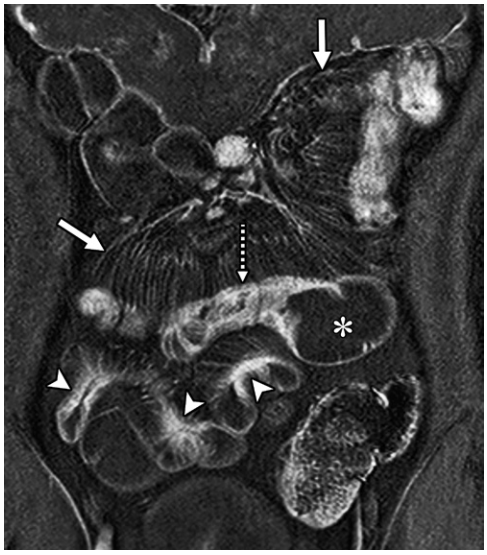


Figure 19. Engorged vasa recta. Coronal contrast-enhanced fat-suppressed T1-weighted MR enterographic image with biphasic oral contrast material shows engorged vasa recta (solid arrows) in the small bowel mesentery owing to active inflammatory Crohn disease in adjacent small bowel segments. This includes several segments that have active inflammation with luminal narrowing (arrowheads) and a stricture with active inflammation (dashed arrow) with mild upstream dilation (*).

clinically suspected. This impression can also be used at follow-up examinations in which there is complete resolution of small bowel and mesenteric inflammatory changes.

Nonspecific Small Bowel Inflammation.—The impression statement "nonspecific small bowel inflammation" (Fig 23) describes bowel loops that have segmental symmetric mural hyperenhancement and/or wall thickening in a patient without a proven Crohn disease diagnosis. Many entities besides Crohn disease can cause this appearance (7,8). Only the location and length of the nonspecific small bowel inflammation should be reported.

Active Inflammatory Small Bowel Crohn Disease without Luminal Narrowing.—"Active inflammatory small bowel Crohn disease without luminal narrowing" (Fig 24) refers to a bowel segment with signs of active inflammation but with a normal luminal diameter in a patient with Crohn disease. This phrase can also be used if there is asymmetric inflammation in the bowel wall in patients without a confirmed diagnosis of Crohn disease.

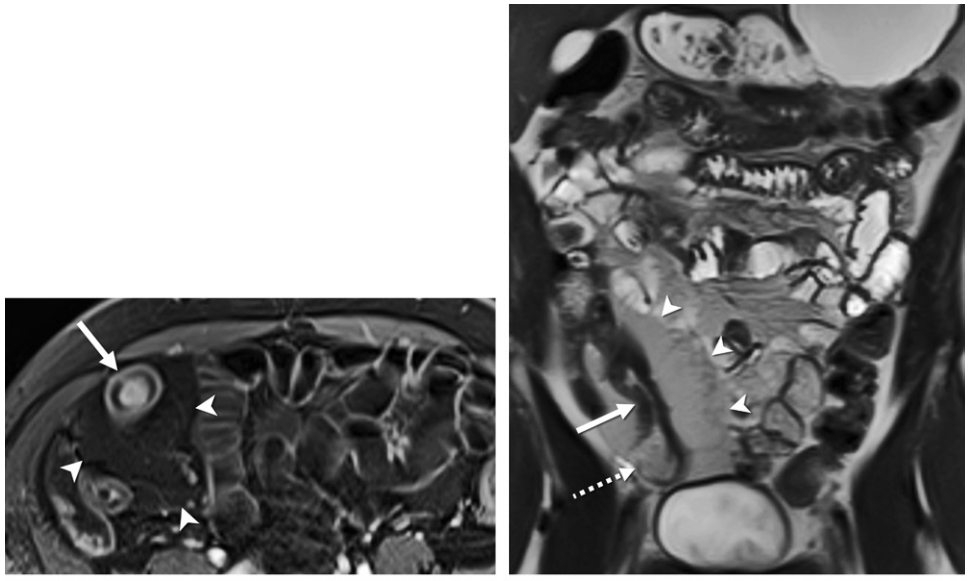
Active Inflammatory Small Bowel Crohn Disease with Luminal Narrowing.—The impression statement "active inflammatory small bowel Crohn disease with luminal narrowing" (Fig 25) indicates an actively inflamed bowel segment with associated luminal narrowing in a patient with Crohn disease.

Crohn Disease with No Imaging Signs of Active Inflammation.—The impression statement "Crohn disease with no imaging signs of active inflammation" (Fig 26) describes a bowel segment with known prior active inflammatory Crohn disease at previous imaging with residual findings, such as asymmetric intramural fat deposition, sacculation, or mild wall thickening without luminal narrowing or signs of active inflammation. Note that using the phrase "Crohn disease with no imaging signs of active inflammation" is preferred rather than using the term *quiescent* or *chronic*.

Stricture Impression Statements

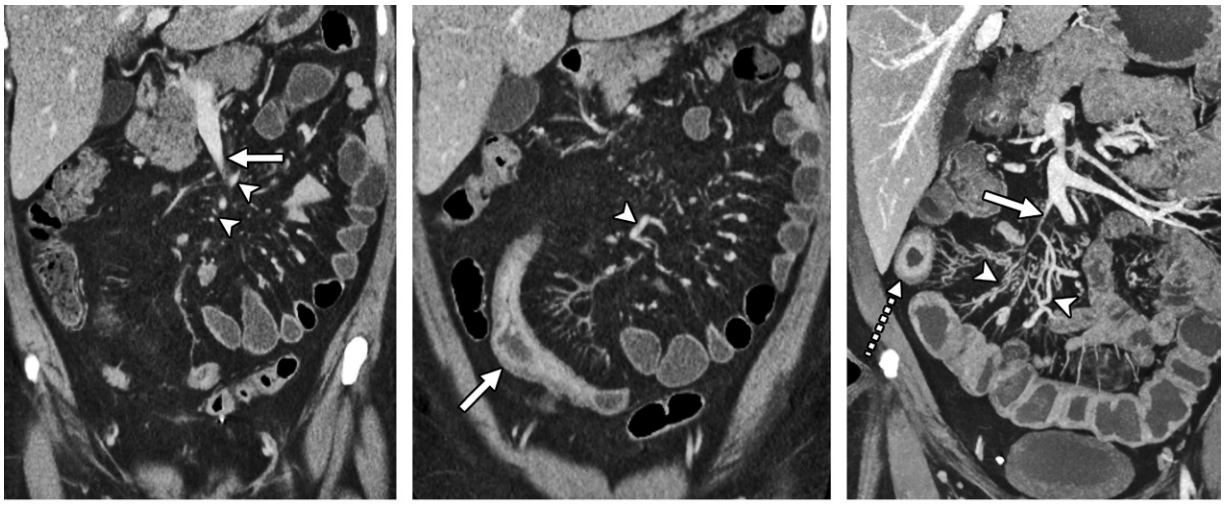
Stricture with Imaging Findings of Active Inflammation.—The statement "stricture with imaging findings of active inflammation" (Fig 27) describes an actively inflamed segment of bowel with luminal narrowing and upstream small bowel dilation. When a stricture is present, it is important to determine whether there is active inflammation in the stricture. Most strictures have varying degrees of active inflammation that should be described and may indicate a role for medical treatment (7,8).

Stricture without Imaging Findings of Active Inflammation.—The impression statement "stricture without imaging findings of active inflammation" (Fig 28) describes a segment of bowel that



a. b.

Figure 20. Fibrofatty proliferation in two patients with Crohn disease. **(a)** Axial contrast-enhanced fat-suppressed T1-weighted MR enterographic image with biphasic oral contrast material shows circumferential fibrofatty proliferation (arrowheads) adjacent to a thick-walled inflamed small bowel segment that has stratified (trilaminar) mural hyperenhancement (arrow). **(b)** Coronal T2-weighted MR enterographic image with biphasic oral contrast material shows eccentric fibrofatty proliferation (arrowheads) adjacent to a thick-walled small bowel segment (solid arrow) with luminal narrowing and mild upstream bowel dilation (dashed arrow), consistent with a stricture with active inflammation.



a. b. c.

Figure 21. Chronic mesenteric venous occlusion in two patients with Crohn disease. **(a, b)** Coronal contrast-enhanced CT enterographic images in the same patient with neutral oral contrast material show chronic occlusion of the superior mesenteric vein (arrow in **a**) and multiple collateral veins in the mesentery (arrowheads). There are diffuse bowel wall thickening and stratified mural hyperenhancement in an adjacent segment of the ileum (arrow in **b**). **(c)** Coronal contrast-enhanced maximum intensity projection CT enterographic image with neutral oral contrast material in a different patient shows interruption of the right ileocolic vein (solid arrow) (consistent with chronic occlusion), multiple dilated mesenteric collateral veins (arrowheads), and a right-sided thick-walled ileal segment (dashed arrow) with stratified mural hyperenhancement.

has wall thickening and luminal narrowing with upstream small bowel dilation without imaging signs of small bowel inflammation (39). These small bowel strictures may show decreased bowel wall signal intensity on T2-weighted MR enterographic images and often have fecalized upstream small bowel contents reflecting the long-standing nature of bowel stasis associated with bacterial overgrowth (Fig 28).

Penetrating Crohn Disease Impression Statements

Penetrating Crohn disease includes a sinus tract (Fig 14), simple fistula (Fig 14), complex fistula

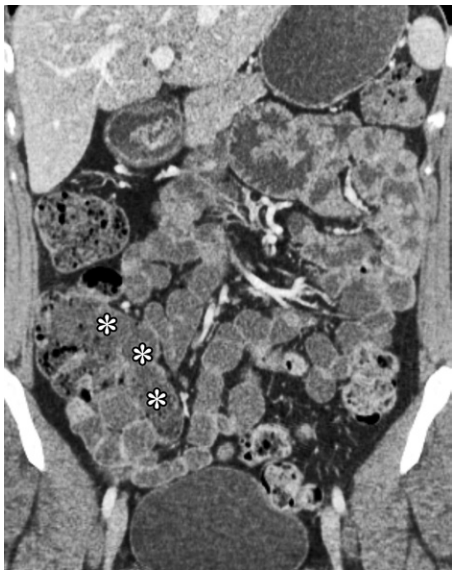
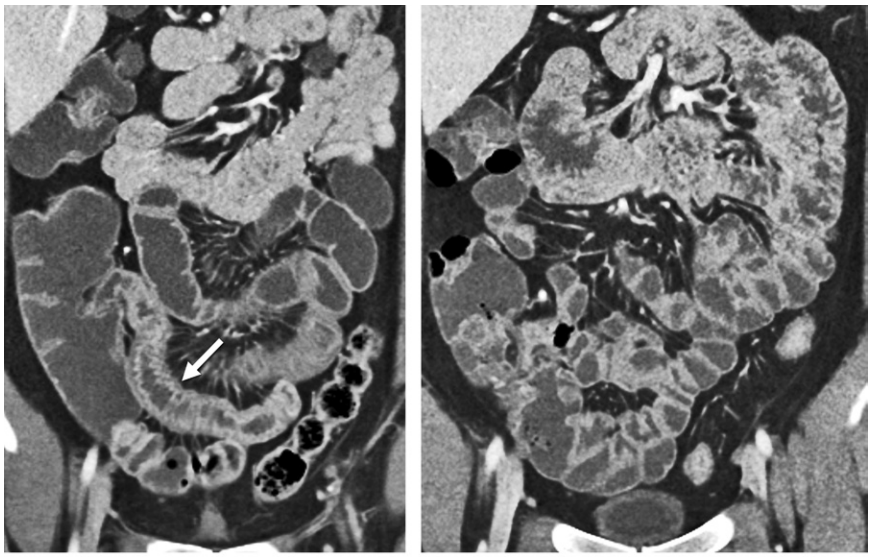
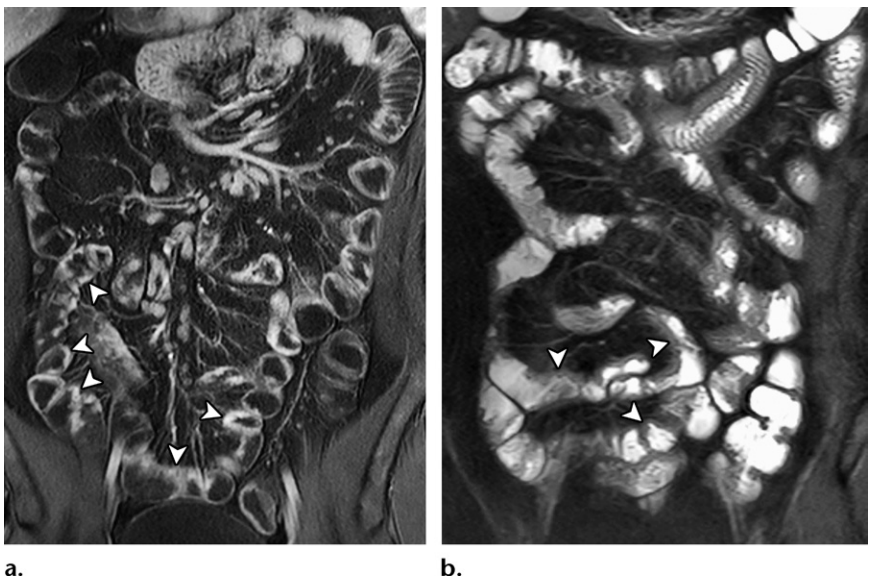


Figure 22. No imaging signs of active inflammation. Coronal contrast-enhanced CT enterographic image with neutral oral contrast material shows normal small bowel throughout the abdomen without wall thickening or bowel dilation, including a normal-appearing terminal ileum (*).



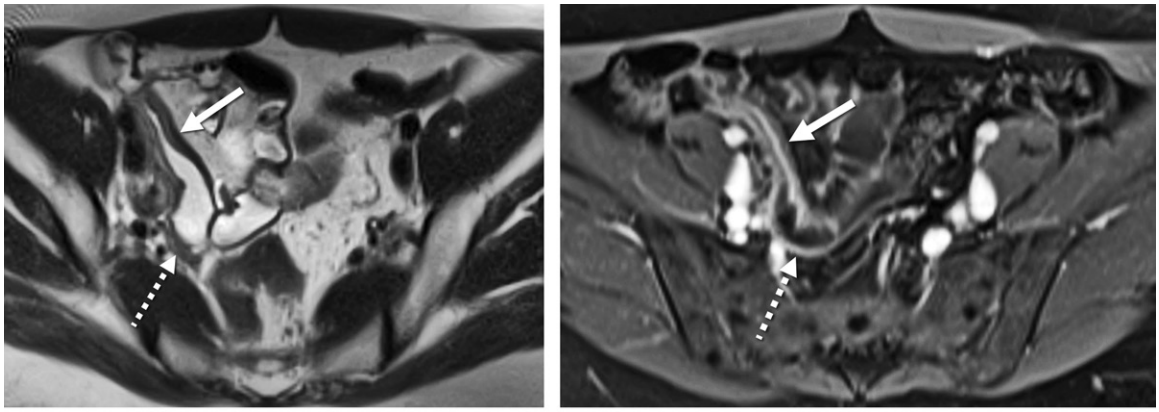
a. **b.**

Figure 23. Nonspecific small bowel inflammation. **(a)** Coronal contrast-enhanced CT enterographic image with neutral oral contrast material shows a long segment of symmetric bowel wall thickening in the distal ileum (arrow) with stratified mural hyperenhancement, consistent with nonspecific small bowel inflammation in a patient without a known diagnosis of Crohn disease. **(b)** Follow-up coronal contrast-enhanced CT enterographic image with neutral oral contrast material performed 2 weeks later shows complete resolution of the wall thickening. Clinically, this was thought to represent an infectious enteritis.



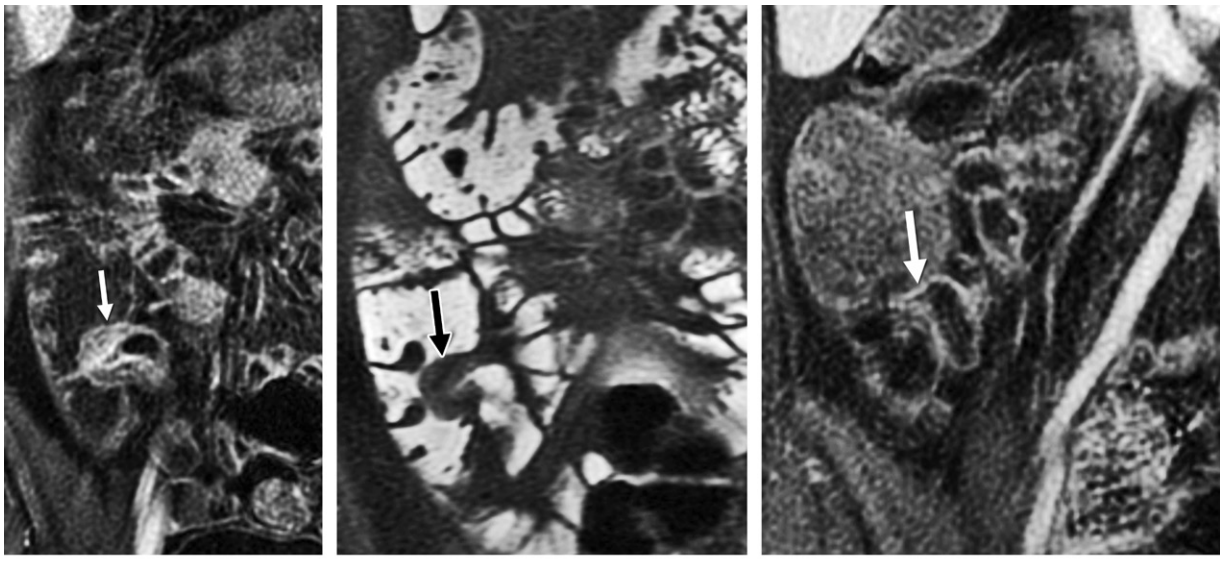
a. **b.**

Figure 24. Active inflammatory small bowel Crohn disease without luminal narrowing. Coronal contrast-enhanced fat-suppressed T1-weighted **(a)** and fat-suppressed T2-weighted **(b)** MR enterographic images with biphasic oral contrast material in a patient with Crohn disease show multiple short small bowel segments with mild mural thickening, mural hyperenhancement, and increased mural T2 signal intensity, predominantly involving the mesenteric side of the bowel segments (arrowheads). The findings are consistent with active inflammatory small bowel Crohn disease without luminal narrowing.

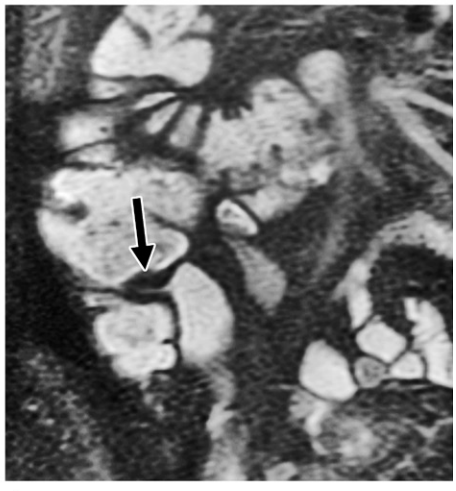


a. b.

Figure 25. Active inflammatory small bowel Crohn disease with luminal narrowing. Axial T2-weighted **(a)** and contrast-enhanced fat-suppressed T1-weighted **(b)** MR enterographic images with biphasic oral contrast material in a patient with Crohn disease show mild wall thickening, mural edema, and stratified mural hyperenhancement (solid arrow) in the terminal ileum, with luminal narrowing but without dilation of the upstream small bowel (which measures <3 cm) (dashed arrow), consistent with active inflammatory small bowel Crohn disease with luminal narrowing.



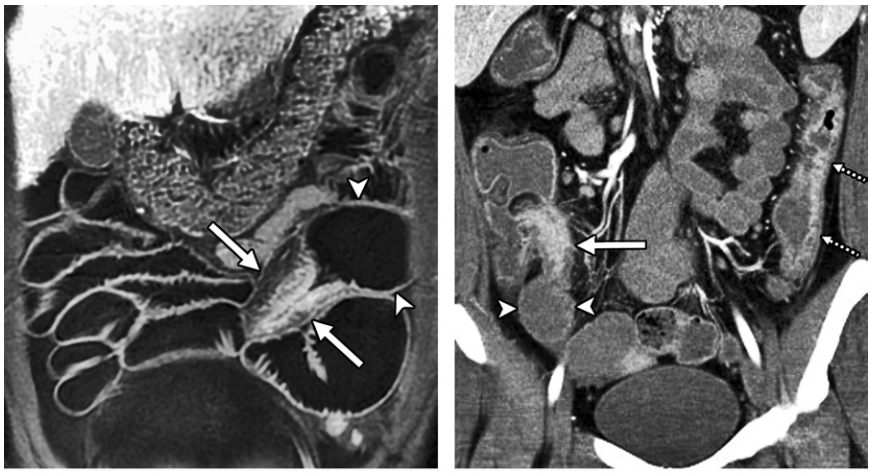
a. b. c.



d.

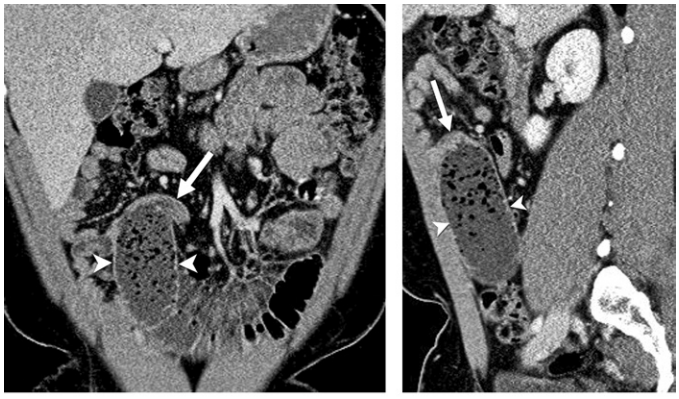
Figure 26. Crohn disease with no imaging signs of active inflammation. **(a, b)** Coronal contrast-enhanced fat-suppressed T1-weighted **(a)** and fat-suppressed T2-weighted **(b)** MR enterographic images with biphasic oral contrast material in a patient with Crohn disease show active inflammation in the terminal ileum (arrow) at the ileocecal valve, with bowel wall thickening, mural edema, and stratified mural hyperenhancement. **(c, d)** Posttreatment coronal contrast-enhanced fat-suppressed T1-weighted **(c)** and fat-suppressed T2-weighted **(d)** MR enterographic images with biphasic oral contrast material show minimal residual wall thickening (arrow), with resolution of the mural edema and hyperenhancement, consistent with Crohn disease with no imaging signs of active inflammation.

(Figs 8, 15), inflammatory mass (Fig 16), abscess (Fig 17), or free perforation. If penetrating Crohn disease is present, this should be reported in addition to stating if bowel inflammation and/or a stricture is present. For example, an impression could state, "stricture with active inflammation associated with an enteroenteric fistula."



a. b.

Figure 27. Stricture with imaging findings of active inflammation in two patients with Crohn disease. **(a)** Coronal contrast-enhanced fat-suppressed T1-weighted MR enterographic image with biphasic oral contrast material shows a segment of ileum with moderate wall thickening, stratified mural hyperenhancement, and luminal narrowing (arrows) associated with moderate to severe upstream small bowel dilation of 5 cm (arrowheads), consistent with a stricture with active inflammation. **(b)** Coronal contrast-enhanced CT enterographic image with neutral oral contrast material shows moderate wall thickening, stratified mural hyperenhancement, and luminal narrowing in the terminal ileum (solid arrow) with mild upstream small bowel dilation (arrowheads), findings consistent with a stricture with active inflammation. There is also active inflammation in the descending colon (dashed arrows).



a. b.

Figure 28. Stricture without imaging findings of active inflammation. Coronal **(a)** and sagittal **(b)** contrast-enhanced CT enterographic images with neutral oral contrast material in a patient with Crohn disease show a short segment with luminal narrowing and mild wall thickening in the mid jejunum (arrow) without mural hyperenhancement or mesenteric inflammatory changes. There is upstream small bowel dilation with fecalization of small bowel contents (arrowheads), a finding consistent with long-standing bowel stasis. The findings are consistent with a stricture without active inflammation.

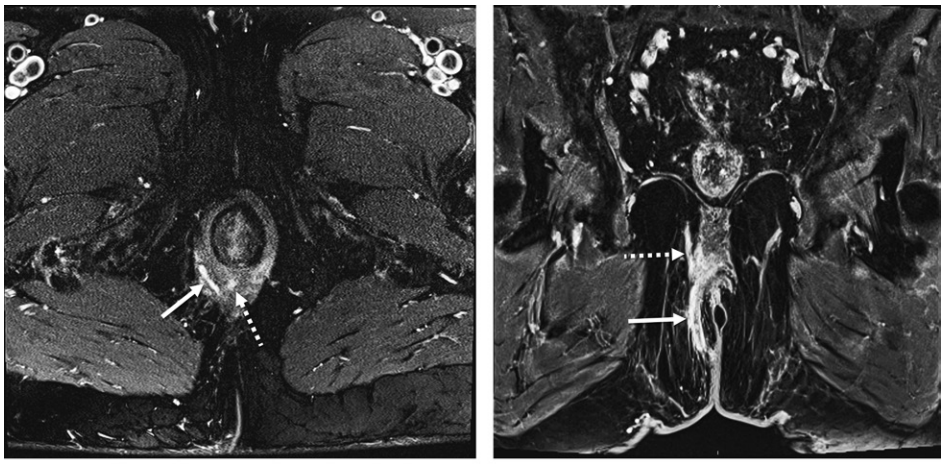
Perianal Crohn Disease Impression Statements

Perianal fistulas generally arise from the rectum or anal canal secondary to deep mucosal ulceration and active inflammation and can extend to the skin surface or any other adjacent epithelial-lined surface (eg, vagina or urethra) (Fig 29). These fistulas do not arise from bowel strictures, as do internal fistulas. When possible, perianal fistulas should be reported using the Park's or St James' classification system (82–85). If a fistula is present, it should be noted if a fistula is simple or complex and if there is an associated abscess. Abscesses may require treatment with antibiotic therapy and/or drainage before administering immunosuppressive or biologic medications (86).

All CT enterographic and MR enterographic examinations that are performed in patients with Crohn disease should include the entire rectum, anal canal, and perineum for complete evaluation. Owing to its higher contrast resolution, MRI is superior to CT for the evaluation of perianal fistulas and abscesses (85). If needed, a dedicated pelvis fistula MRI protocol can be performed that includes obtaining high-spatial-resolution small-field-of-view (15–20 cm) fat-suppressed and non–fat-suppressed T2-weighted, fat-suppressed contrast-enhanced T1-weighted, and diffusion-weighted images (87).

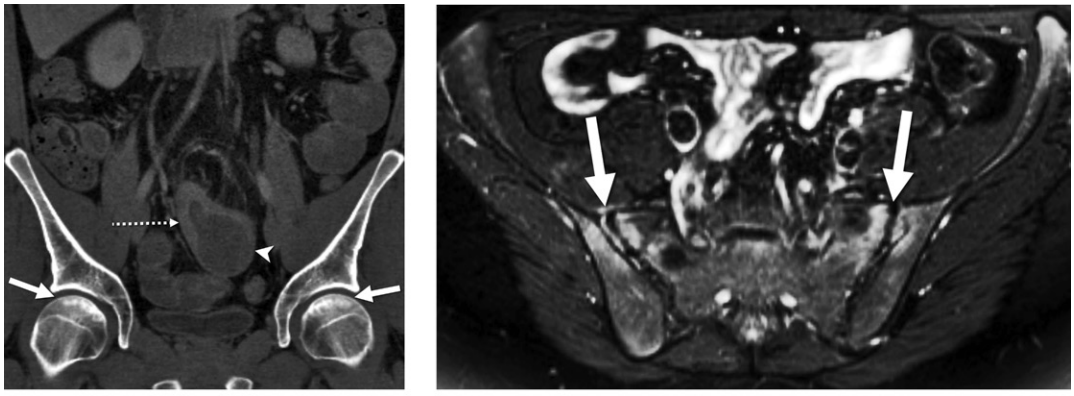
Impression Statements for Other Complications

Other possible complications that should be evaluated for at CT enterography and MR



a. b.

Figure 29. Perianal Crohn disease. **(a)** Axial T2-weighted fat-suppressed MR image shows a transphincteric perianal fistula, which arises from the posterior midline (6-o'clock position) (dashed arrow) and crosses the external sphincter on the right (solid arrow). **(b)** Coronal contrast-enhanced fat-suppressed T1-weighted MR image shows inferior extension of the fistula into the inferomedial gluteal fold (solid arrow) and superior extension into the ischiorectal fossa (dashed arrow).



a. b.

Figure 30. Bone complications in two patients with Crohn disease. **(a)** Coronal contrast-enhanced CT enterographic image (bone window) with neutral oral contrast material shows crescent-shaped areas of subchondral sclerosis in the femoral heads (solid arrows), findings consistent with bilateral femoral head avascular necrosis. Not as well visualized on this bone window image is small bowel wall thickening (dashed arrow) and upstream small bowel dilation (arrowhead), findings consistent with a stricture with active inflammation. **(b)** Axial fat-suppressed T2-weighted MR enterographic image with biphasic oral contrast material shows edema within and on both sides of the sacroiliac joints (arrows), consistent with bilateral sacroiliitis.

enterography include femoral head avascular necrosis, sacroiliitis, primary sclerosing cholangitis, pancreatitis, mesenteric venous thrombosis or chronic mesenteric venous occlusion, neoplasm, cholelithiasis, and nephrolithiasis (68,88–90) (Figs 21, 30, 31).

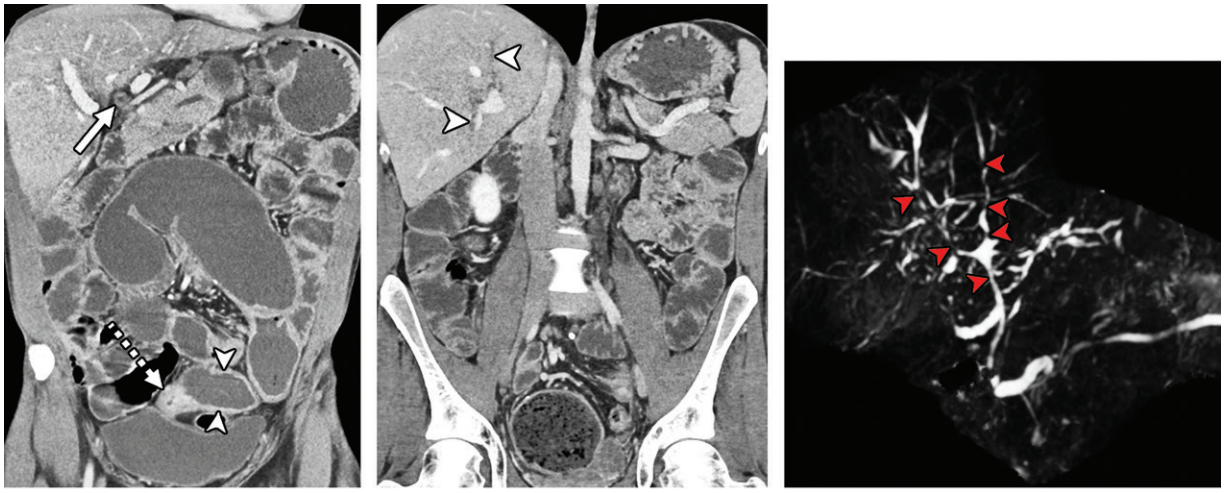
Additional Interpretation Guidelines

Signs of Small Bowel Inflammation

The signs of small bowel inflammation on CT enterographic and MR enterographic images include the following: *(a)* bowel wall thickening greater than or equal to 3 mm; *(b)* mural and perienteric edema; *(c)* segmental mural hyperenhancement; *(d)* restricted diffusion when active inflammation is depicted on contrast-enhanced and/or T2-weighted MR images (53,56); and *(e)* ulcerations (7,8,11,21,91).

When to Diagnose Crohn Disease at CT Enterography and MR Enterography

It is appropriate to indicate that inflammatory small bowel Crohn disease is likely when mural hyperenhancement and wall thickening are present and the patient has a history of Crohn disease. It is also appropriate to indicate that inflammatory small bowel Crohn disease is likely when small bowel inflammation is asymmetric (more severe along the mesenteric border of the bowel) or if bowel inflammation coexists with penetrating complications typical of Crohn dis-



a. b. c.

Figure 31. Biliary complications. **(a, b)** Coronal contrast-enhanced CT enterographic images with neutral oral contrast material in a patient with Crohn disease show common hepatic duct wall thickening (solid arrow in **a**) and irregular intrahepatic biliary duct dilation (arrowheads in **b**), findings concerning for a primary sclerosing cholangitis (PSC) diagnosis. Note the wall thickening, mural hyperenhancement, and luminal narrowing in a segment of ileum in the pelvis (dashed arrow in **a**) with upstream bowel dilation (arrowheads in **a**), findings consistent with a stricture with active inflammation. **(c)** Follow-up coronal maximum intensity projection MR cholangiopancreatographic image confirms the diagnosis of PSC and shows multiple intrahepatic and extrahepatic bile duct strictures (arrowheads).

Table 5. Terminology in Radiology Reports

Terms Not to Use	Replacement Phrases
Acute inflammation	Active inflammation
Fibrostenotic	Stricture without active inflammation
Penetrating ulcer	Ulcer
Phlegmon	Inflammatory mass
Quiescent	Crohn disease with no imaging signs of active inflammation

ease (after excluding other causes of penetrating complications such as appendicitis, diverticulitis, neoplasm, or tuberculosis), even if there is no known history of Crohn disease (7, 8, 92).

Terms That Should Not Be Used in Radiology Reports and Replacement Phrases

Several terms have historically been used in Crohn disease CT enterography and MR enterography radiology reports that can potentially be ambiguous and unclear. These terms are listed in Table 5 along with their respective replacement phrases. However, several terms such as *chronic*, *active on chronic*, and *active on quiescent* have no replacement and should not be used at all. When in doubt, please refer to the recommended radiology report impression statements listed in Table 4 (7, 8).

Conclusion

In this article by the Society of Abdominal Radiology Crohn's Disease–Focused Panel, many of the CT enterographic and MR enterographic imaging findings of small bowel Crohn disease and the recommended standardized radiology report impression statements based on previous consensus recommendations are illustrated. Additional interpretation guidelines for reporting Crohn disease at CT enterography and MR enterography are also presented. This recommended standardized nomenclature can be used to generate radiology report impression statements that clinicians can rely on when formulating treatment and follow-up plans.

Author Affiliations.—From the Department of Radiology, Thomas Jefferson University Hospital, 132 S 10th St, Philadelphia, PA 19107 (F.F.G.); Department of Radiology, Children's Hospital of Philadelphia and University of Pennsylvania, Philadelphia, Pa (S.A.A., K.D.); Department of Radiology (J.G.F., J.L.F.) and Division of Gastroenterology and Hepatology (D.H.B.), Mayo Clinic, Rochester, Minn.; Department of Radiology, University of Michigan Health System, Ann Arbor, Mich (M.M.A.); Department of Radiology, Cincinnati Children's Hospital Medical Center, University of Cincinnati College of Medicine, Cincinnati, Ohio (J.R.D.); Department of Radiology, Rhode Island Hospital, Providence, R.I. (D.J.G.); Department of Radiology, Icahn School of Medicine at Mount Sinai, New York, NY (M.C.); Imaging Institute, Cleveland Clinic, Cleveland, Ohio (N.S.G.); Department of Radiology, Massachusetts General Hospital, Harvard Medical School, Boston, Mass (M.S.G.); Department of Radiology, University of Florida College of Medicine, Gainesville, Fla (J.R.G.); Department of Radiology, New York University Langone Health, New York, N.Y. (C.H.); Department of Radiology, Duke University Medical Center, Durham, N.C. (T.A.J.); Department of Radiology, University of Ulsan College of Medicine, Asan Medical Center, Seoul, South Korea (S.H.P.); Department of Radiology, Hospital Clínic of Barcelona, Barcelona, Spain (J.R.); Department of Radiology, Boston University Medical Center, Boston, Mass (J.A.S.); Department of Radiology, Icahn School of Medicine at Mount Sinai,

New York, NY (B.T.); Centre for Medical Imaging, University College London, London, United Kingdom (S.A.T.); and Imaging Institute, Cleveland Clinic, Cleveland, Ohio (M.E.B.).

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Invited Commentary on "Small Bowel Crohn Disease at CT and MR Enterography: Imaging Atlas and Glossary of Terms"

From:
Johannes T. Heverhagen, MD, PhD
University Institute for Diagnostic, Interventional and Pediatric Radiology, Inselspital University Hospital, Bern
Bern, Switzerland

The prevalence of Crohn disease in developed Western countries has increased over the past decades. Currently, approximately 800000 patients in the United States and one million patients in Europe are diagnosed with Crohn disease. The incidence of the disease is also increasing in developing countries in Eastern Europe, Asia, South America, and Africa. While the disease cannot be cured, several treatments exist that are able to modify the disease and enable long-term remission. However, owing to complications, surgery might be the only option for some patients. Therefore, it is important to identify and monitor the extent of activity and involvement of the disease, as well as the presence of complications noninvasively (1,2). Moreover, monitoring disease progression as well as evaluating the response to medical treatment needs to be achieved noninvasively. Cross-sectional imaging of the small bowel in patients with suspected Crohn disease using CT enterography or MR enterography has become the standard to identify the extent, activity, and involvement of the disease, as well its complications (1,2). Therefore, several subspecialty societies, including the Society of Abdominal Radiology, the American Gastroenterological Association, and the Society of Pediatric Radiology, have established recommendations for interpreting and reporting imaging findings in patients with Crohn disease and emphasize the importance of standardized nomenclature. These consensus statements were recently published (3)[11].

In this article, Guglielmo et al (4) provide examples that illustrate the recommendations of this consensus statement. The authors outline how the standard nomenclature should be used in specific clinical settings and how imaging find-

11 These guidelines were jointly published with the journal Gastroenterology, and both are cited in article by Gugliemo et al. Would you like to include that reference as well? If yes, I will update the subsequent references. Thank you!

ings should be reported. Moreover, they provide guidelines for how these examinations should be interpreted. This is a major additional benefit for the reader, as the original consensus statement had limited space for illustrations. Therefore, the authors provide the reader with an extended image database that will help the reporting radiologist reference the findings. The recommended standardized nomenclature presented here can be used to generate radiologic report dictations. These standardized reports will help guide medical and surgical management in patients with small bowel Crohn disease.

The major strength of this article is that it provides a practice guideline for the practicing abdominal radiologist. It provides detailed descriptions on how to interpret and report bowel-imaging findings, signs of penetrating Crohn disease, and mesenteric imaging findings. For each finding, example images are provided and standardized nomenclature that can be used to report them is recommended. The individual radiologist or radiology department can use this to generate a template for structured reports. In addition, the authors recommend how to report impression statements for inflammation, strictures, penetrating Crohn disease, perianal Crohn disease, and other complications. They also provide terms that should not be used in radiology reports and recommend phrases that should replace these terms. This is also an important aspect of this article, as it emphasizes the standardization of the radiology report language.

A weakness of this article is that it does not provide guidelines or recommendations on how to best perform MR enterography or CT enterography. As a good radiology report can only be generated if the images obtained are of good quality, it is mandatory to provide guidelines on how these images should be obtained. As this is likely beyond the scope of this article, the authors could have provided references on this topic. There are several manuscripts published that provide such recommendations (5–8). The reader needs recommendations for imaging parameters, including type of sequence, contrast agent administration, and timing. Moreover, they need instructions on bowel distention, patient preparation, and other guidelines that help to generate the best images possible. The reader also needs to know how they should evaluate the accuracy of the technique as well as image quality.

The article by Guglielmo et al (4) in this issue of *RadioGraphics* is an excellent extension of the consensus recommendations for evaluation, interpretation, and utilization of cross-sectional imaging enterography in patients with small bowel Crohn disease (3). Radiologists should be aware of these findings and their importance as they interpret and report CT and MR enterographic examinations to identify the extent, activity, and involvement of the disease, as well as its complications.

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