Imaging Techniques in the Evaluation of Inflammatory Bowel Disease: What Every General Radiologist Should Know

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Learning objectives

Computed tomography enterography (CT-E) and Magnetic Resonance enterography (MR-E) are the imaging modalities of choice for the assessment of bowel inflammatory disease with comparable diagnostic performance in detecting inflammatory activity in entities like Crohn’s Disease. Accurate interpretation of these examinations requires an understanding of the anatomy, pathophysiology and patterns of disease. Technical factors of Computed Tomography (CT) and Magnetic Resonance (MR) examination are also important.

The objectives of this exhibit are:

- To Illustrate the normal anatomy of the gastro-intestinal (GI) system on CT-E and MR-E.
- To Review inflammatory bowel disease's pathophysiology.
- To Explain the role of CT-E and MR-E in the evaluation of mural and penetrating bowel's inflammatory disease.
- To Recognize key imaging findings of Crohn's Disease and Ulcerative Colitis.
Background

Inflammatory bowel disease is a chronic condition secondary to uncontrolled immune response in the gastrointestinal mucosa, which has gastrointestinal, and systemic (nonspecific) manifestations and complications. The incidence of this disease has increased worldwide, with a higher incidence in developed countries. Crohn's disease (CD) and ulcerative colitis (UC) are the two pathologies most representative in this group.

There are multiple predisposing elements described, which include genetic, nutritional, infectious and environmental factors; Enteritis, perinatal or infant infection or vaccination against measles, mycobacteria and oral contraceptives among others.

In accordance with the literature, breastfeeding is a protective factor against CD and UC. In the other hand, smoking increases the risk of development and recurrence of CD and decreases the risk of developing UC.

The first episode of CD usually occurs between 20 to 30 years, while the first manifestation of UC occurs between 30-40 years.

CT-E and MR-E are the imaging modalities of choice for the investigation of bowel inflammatory disease with comparable diagnostic performance in detecting inflammatory activity. Accurate interpretation of these examinations requires an understanding of the anatomy, pathophysiology and patterns of disease. Technical factors of the CT and MR examination are also important.

In order to distinguish normal from abnormal appearance of bowel, it is important to understand and recognize the normal components of intestinal segments.

1. Normal anatomy of bowel in CT and MR enterography

The small intestine is composed of the duodenum, jejunum, and ileum. The duodenum is the first part of the small intestine, starts at the pylorus junction and extends to the duodeno-jejunal junction and is approximately 25 cm in length.

The jejunum begins at the duodenojejunal flexure which is suspended by the ligament of Treitz. Represents about 40% of the length of the intestine. It has thicker, more vascular wall with closely spaced circular folds also referred to as valvulae conniventes, or plicae circulares (Figure 1). The prominence of folds and wall thickness vary by age and degree of bowel distention.
The ileum has no clear point of distinction with the jejunum. Constitutes the major portion of the distal intestine, has thinner wall, less vascular and more widely spaced circular folds, compared to the jejunum, and ends at ileocecal valve.

Normal appearance of the intestine is characterized by an average diameter of duodenum of 2.5 cm, jejunum: 2.5 cm, proximal ileum: 2 cm distal ileum 1.9 cm and 1.9 cm of terminal ileum. The wall thickness along the entire small bowel is symmetric, measuring between 1-2 mm.

The large intestine is approximately 150 cm long; its lumen is wider than that of the small intestine. Begins at the ileocolic junction and extends to the anal canal. It is composed by the cecum, appendix, ascending colon, right colic flexure, transverse colon, left colic flexure, descending colon, sigmoid colon, and rectum. It has unique structures that differentiate it from the small intestine like the Teniae coli, narrow thickenings of the muscularis externa beneath the serosal surface distributed along the large bowel with exception of appendix and rectum. The teniae coli are 3 in number, their width remains relatively constant and form sacculations called haustra, which are small saccations along the length of the large intestine (Figure 2). Normal colonic wall diameter is in the range of 2-3 mm.

2. Pathophysiology

Inflammatory bowel disease comprises a group of chronic diseases that result from an unregulated immune response to luminal agents associated with genetic and environmental factors. The normal intestinal flora of these patients are unable to eliminate pathogenic flora, causing chronic inflammation.

Crohn's disease is characterized by transmural inflammation with neutrophil infiltration and abscess formation in the active phase. During the chronic phase atrophic changes and destruction of the crypts are present. Ulcers are formed around lymphoid aggregates and are usually located in the mesenteric border.

Ulcerative colitis is characterized by the presence of mucosal and submucosal inflammatory infiltrates of neutrophils and abscess formation. Ulcers are usually superficial and large. Non inflammed areas located between areas of ulceration can be found.

3. CT and MR tecniques

CT-E and MR-E are the modalities of choice for the assessment and monitoring of the disease, evaluating the appearance of the mucosa, extra intestinal manifestations and associated complications.
3.1 CT Enteroclysis - CT Enterography

This technique combines the spatial and temporal resolution of the CT with the bowel distension using large volumes of oral contrast (1500 - 2000 mL) and intravenous contrast.

Bowel distension can be achieved administering negative intestinal contrast media through a naso-jejunal tube (CT-Enteroclysis) or per oral intake (CT-Enterography).

At our institution the protocol begins with the insertion of an enteral tube under fluoroscopic guidance, leaving the tip of the tube in the proximal segment of the jejunum. Subsequently, 2000cc of normal saline through the enteral tube and 75cc of iodinated contrast (Ioversol) through the right antecubital vein are administered. Volumetric portal-phase CT images are acquired using a 64-slice equipment, and multiplanar reconstructions are performed (Figure 3).

The administration of saline through the nasojejunal tube ensures uniform bowel distension, which allows adequate assessment of the intestinal wall, pattern of mucosa enhancement and fatty infiltration. Additionally it allows the assessment of the entire abdomen and permits detection of extra intestinal manifestations. Within the contraindications for this study we encounter contrast agent allergies, pregnancy and renal failure.

The characteristic findings on inflammatory bowel disease can be divided in acute and chronic according to the stage of disease.

FINDINGS IN ACUTE STAGE:
- Wall thickening greater than 3 mm and mucosal hyperenhancement (Figure 4).
- Stranding of adjacent mesenteric fat.
- Intramural edema: hypodense layer located between the muscular and enhancing mucosal wall layers (Figure 5).
- Mucosal Ulcers: Early finding which reflects active inflammation (Figure 6).

FINDINGS IN CHRONIC STAGE:
- Submucosal fat deposition, giving the wall a trilaminar appearance (Figure 7).
- Wall deposition of fibrosis, with consequent strictures, which may cause bowel obstruction. Bowel strictures demonstrate late enhancement following contrast administration (Figure 8).
- Fibrofatty proliferation of adjacent mesenteric fat (Figure 9)
Usually, acute and chronic stage findings can be superimposed within different bowel segments in the same patient.

3.2 MR Enterography (MR-E)

It is a useful method to identify the location, extent and degree of activity of the disease, with similar diagnostic accuracy to CT-E. Among the advantages of this technique are: Adequate contrast and temporal resolution, Dynamic evaluation in cine sequences and absence of radiation. The disadvantages of this diagnostic method include high cost, motion artifact and time consuming.

The examination requires 8-hour fast, intake of intestinal contrast agents (20 cc of iodinated contrast diluted in 1000 to 1500 cc of normal saline). Other options of contrast media include normal saline - Barium + sorbitol. We use a dose of an antispasmodic agent (hyoscine) 2 hours before the test. Some protocols also administer metoclopramide to allow proper gastric emptying when administered.

MR Sequences recommended include:

- Axial and coronal single shot fast Spin-Echo T2WI with and without fat saturation.
- Axial Gradient-Echo T1WI with fat saturation.
- Axial and coronal T2 with dynamic acquisitions (cine).
- Axial and coronal volumetric fat saturated Gradient-Echo T1WI before and following contrast administration.

T2WI demonstrate mucosal changes (ulcers), degree and signal intensity of wall thickening (Figure 10), and inflammatory changes of the adjacent mesenteric fat. Post contrast T1WI allow the identification of mucosal enhancement to differentiate between acute (early enhancement) and chronic stages (late enhancement). Fat saturated images allow delineation of the bowel wall, identification of mesenteric edema and differentiation between edema and focal fatty infiltration of the wall.

Wall thickening greater than 3 mm, wall hyperemia (Figure 11), transmural ulceration, fistula formation, vascular engorgement and enlarged mesenteric lymph nodes are indicate active inflammatory disease.

Bowel wall fat infiltration, mesenteric fibrosis and stricture formation are indicative of chronic stage of the disease
3.3 CT and MR Enterography. Which one to use?

The advantages reported for CT-E include: less time consuming, lower cost compared with MR and high space resolution. However, due to the radiation exposure is not considered the method of choice in young patients or those with chronic disease that require serial followup.

In contrast, in patients acutely ill, CT-E is useful for identifying complications such as perforation or intestinal obstruction.

MR-E is preferred in young patients that require serial imaging follow up, and in those with allergy to iodinated contrast agents. It is particularly useful for detection of enteric fistulas and determination of the degree of disease activity (Table 1).
Fig. 1: Coronal reconstruction of CT enteroclysis demonstrates the morphology of the jejunum with the characteristic valvulae conniventes (yellow circle) and its difference with the ileum (red circle) in which the wall is less prominent.

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Fig. 2: Coronal CT reconstruction of CT enteroclysis demonstrate the characteristic saculations of the large bowel called haustra (arrow) formed by the teniae coli.

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**Fig. 3:** CT scout view (right) demonstrates the tip of the nasogastric tube in jejunum. Coronal Reconstruction of CT enteroclysis demonstrating the distention of the small bowel with the negative contrast media.

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**Fig. 4:** Axial CT enterography of a 71 year old patient with Crohn's disease demonstrates thickening (7.4mm) and enhancement of the ileum walls.

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Fig. 5: 39 year old patient with Crohn's disease. Axial CT Enterography (left) and Coronal reconstruction (right) demonstrates transmural thickening of the terminal ileum and intense mucosal enhancement (arrows). Note the intramural edema as hypodense layer located between the muscular and the enhanced mucosa.

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**Fig. 6:** Coronal T2WI demonstrates ileum wall discontinuity in keeping with wall ulceration representing active inflammation.

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**Fig. 7:** Axial CT of a patient with Crohn’s disease demonstrates submucosal fat deposits within the intestinal wall (arrows) due to chronic inflammatory changes.

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**Fig. 8:** Axial T2WI (a) and Gradient echo (b) of MR enterography demonstrates fibrotic changes of Crohn’s disease with luminal stenosis and low signal intensity of the ileal wall. Axial post contrast T1WI (c) demonstrates late enhancement of the wall due to collagen deposition in mucosa and submucosa.

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**Fig. 9:** Axial CT of a patient with history of Crohn's disease in chronic stage demonstrating fibrofatty proliferation (arrows) adjacent to terminal ileum “Creeping fat”.

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Fig. 10: MR Enterography. Axial (right) and coronal (left) T2WI demonstrate wall thickening of the distal ileum (arrows). Note low signal intensity of the wall of the segment involved due to chronic inflammatory changes.

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**Fig. 11:** 11 year old patient diagnosed with Crohn’s disease. Axial post contrast T1WI demonstrates wall thickening of the terminal ileum with intense mucosal and serosal enhancement (hyperemia).

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**Table 1:** Suggested preferences in the choice of the technique for the evaluation of bowel inflammatory disease according to the clinical scenario and patient characteristics.

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Findings and procedure details

4. Imaging Evaluation

Non invasive imaging assessment allows adequate identification of the location, extent and degree of disease activity.

They also establish intra and extra-intestinal complications, assess treatment response and relapse, and guides further invasive procedures for adequate diagnosis, such as endoscopy and/or biopsy samples.

Imaging exams are also useful in disease follow up, determination of chronic changes as fibrosis or stenosis and complications as abscess, fistula, perforation and perianal fistulas.

4.1 Imaging Findings in Crohn's disease

This condition mainly involves the terminal ileum and cecum, however it can affect any segment of the gastrointestinal tract from mouth to the anus. In 70% of patients there is involvements of the small intestinal; the terminal ileum and ileocecal region are involved in 90%, the ileum and colon between 40-50% and in 15-25% of the patients the disease only affects the colon (Figure 12).

It is characterized by discontinuous lesions and eccentric, transmural inflammation (Figure 13) which can progress to fibrosis, stenosis and fistula formation. The wall thickening usually occurs in the mesenteric border of the colon and is associated with inflammatory changes of the mesenteric fat. (Figure 14).

Maglinte et al, proposed a system of classification of Crohn's disease based on the imaging findings. This system classifies the disease in four stages:

1. Active (no fistulas or stenosis)
2. Penetrating (with fistulas and / or abscesses).
3. Fibrostenotic (areas of stenosis).
4. Reparative

KEY FINDINGS IN THE ACTIVE PHASE:
- Thickening of the mucosa >3mm.
- Submucosal edema, wall thickening, increased signal intensity of the intestinal wall in T2WI. (Figure 15, 16).
- Mucosal Enhancement on post contrast T1WI.
- Vascular engorgement.
- Mesenteric lymphadenopathy.
- Formation of fistulas or abscesses.

**KEY FINDINGS IN PENETRATING PHASE:**
Deep ulceration generates transmural inflammation, which can progress to formation of fistulas (Figure 17), stenosis or abscesses (Figure 18). Dynamic cine acquisitions enable evaluation of intestinal motility and distinction between an area of stenosis or transient narrowing.

The fistulas can be developed between an inflamed segment and other intestinal loop, colon, stomach, bladder or skin; in this cases a linear path with enhancement is identified, extending from the inflamed segment to the adjacent structure. Abscesses are typically adjacent to the involved segment.

**KEY FINDINGS IN FIBRO- STENOTIC PHASE:**

The characteristic finding at this stage of the disease is the mural fibrosis with development of areas of stenosis. Fibrosis is associated with complications such as intestinal obstruction (Figure 19).

The findings in the MR enterography indicative of fibrotic changes include:

- Intestinal wall isointense to muscles on T1WI and T2WI.
- Dilatation of the proximal intestine with absence of early mucosal enhancement.

**KEY FINDINGS IN REPARATIVE PHASE:**

During this phase an asymmetrical involvement of the intestinal wall is observed. There is polyp formation associated with areas of stenosis without obstructive pattern and without evidence of edema or hyperemia.

4.2 Imaging Findings in Ulcerative colitis:

This condition is characterized by a continuous involvement of the colon. The inflammation is limited to the mucosa and submucosa wall-layers and the lesions can reach the cecum. The rectum is often involved in 95% of cases, demonstrating luminal narrowing, mural thickening, proliferation of perirectal fat and widening of the presacral space.

The heterogeneous enhancement and thickening of the wall grater than 3 mm are typical findings (Figure 20 and 21), fatty infiltration of the wall is observed in 60% of the
patients. Other findings are mesenteric lymph nodes of inflammatory appearance and engorgement of mesenteric vessels.

The changes associated with chronic disease are loss of haustras, stricture formation, stiffness and fatty infiltration. Ulcerative colitis is associated with a high risk of colorectal cancer, which increases according with the duration and the degree of involvement of the disease. Patients diagnosed with ulcerative colitis and Crohn's disease benefit from annual colonoscopy surveillance.
Fig. 12: Axial CT images of a 21 year old patient with Crohn's disease in chronic stage demonstrates wall thickening of the ascending, descending and sigmoid colon (arrows).

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**Fig. 13:** Coronal T2WI and post contrast T1WI of a 62 year old patient with Crohn's disease demonstrates wall thickening and mucosal enhancement of the terminal ileum (arrows) due to acute inflammatory involvement.

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**Fig. 14:** Axial CT of a patient with Crohn Disease demonstrates concentric wall thickening of the distal ileum. Stranding of mesenteric fat adjacent the distal ileal loops (arrow) are identified.

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Fig. 15: MR Enterography of a 49 year old patient with Crohn’s disease. Axial T2WI (a and b) demonstrates wall thickening and increased signal intensity of the terminal ileum (arrows). Axial postcontrast T1WI (c and d), demonstrating also enhancement of the wall due to inflammatory involvement (arrows).

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**Fig. 16:** Coronal postcontrast T1WI (right) and T2WI (left) of a 49 years old patient demonstrates significant thickening of a long segment of the ileum, associated with ascites (arrow) due to inflammatory changes.

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**Fig. 17:** Axial CT (right) of a patient with a history of Crohn's disease and partial resection of a bowel segment, demonstrates oral contrast leakage into the abdominal wall. Sagital Reconstruction (right) shows the fistulous tract (arrow).

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**Fig. 18:** Axial CT of a patient with history of Chron’s disease demonstrates a hypodense collection (abscess) between the ileal loops (arrows), with marked wall thickening of the adjacent bowel segment.
Fig. 19: Coronal CT Enteroclysis reconstruction of a patient with a history of Crohn’s disease demonstrating concentric transmural wall thickening of the distal ileum (arrow) with consequent retrograde obstructive effect.
Fig. 20: MR Enterography of a patient with history of ulcerative colitis demonstrates continuous and diffuse wall thickening of the colon with early enhancement of the mucosa.

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Fig. 21: MR enterography of a 39 year old patient with history of ulcerative colitis. Axial T2WI (a) demonstrates wall thickening of the different portions of the colon (arrows). Axial postcontrast T1WI (b) with early enhancement of colonic mucosa due to acute inflammatory involvement (arrows).

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Conclusion

- Knowledge of the pathophysiology of bowel inflammatory disease is pivotal in the understanding of CT-E and MR-E findings.

- The location, extent, activity and severity of inflammatory bowel disease can be accurately assessed by MR-E and CT-E.

- Cross sectional images provide information not only about the bowel and its walls. It also depicts the mesenterium and related findings of surrounded structures.

- MR-E is the preferred imaging modality for diagnosis and follow up of patients with chronic inflammatory bowel disease, that require serial imaging follow up, and for treatment response evaluation.

- CT-E is the modality of choice for patients with acute abdominal presentation.
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