A simple guide to MR enterography in Crohn´s disease

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Learning objectives

1. Basics of small bowel MR protocols
2. Indications of MR enterography in the study of Crohn's disease
3. Important MR findings in Crohn's disease
4. Challenges and pitfalls of MR small bowel

Background

Crohn's disease is a multifactorial chronic inflammatory condition characterized by discontinuous, segmental and multifocal distribution involving any part of the gastrointestinal tract, particularly the small bowel and the terminal ileum. It has an unpredictable course that includes frequent acute relapses and various manifestations and levels of severity, such as intestinal fistulas (particularly after surgical intervention), abscesses or bowel obstruction.

Young patients between the 2nd to 4th decades of life are commonly affected by the disease, and more prone to feel the adverse effects of repeated exposure to ionizing radiation.

From a pathologic point of view, Crohn's Disease is characterized by full-thickness bowel wall inflammation with formation of non-necrotizing granulomas. Penetrating wall ulcers may develop and end up in bowel perforation and fistulas. Intestinal fibrosis can occur in chronic stages of the disease.

Management of Crohn's disease is based in long-term maintenance and treatment of acute recurrences. Surgical resection of the affected bowel segment is considered when medical treatment fails to control symptoms and should be restricted to short damaged areas.

It is important to assess Crohn's Disease inflammatory activity as predominance of acute inflammatory changes or intestinal fibrosis in an acute relapse or in the setting of intestinal obstruction, will determine the medical and/or surgical approach.

The study of patients with Crohn's Disease requires clinical examination and laboratorial, endoscopic, histological and radiological techniques. All these techniques combined will appraise Crohn's Disease activity and allow adequate treatment planning.
Indications: MR enterography is usually performed in patients with established diagnosis of Crohn's Disease to evaluate:

- Activity of the disease (active inflammation or fibrotic quiescent disease)
- Extension of the disease
- Acute relapse with suspicion of stricture and/or intestinal obstruction
- Treatment failure
- Suspicion of complications

Imaging findings OR Procedure details

Based in 40 MR-E studies from patients with Crohn's Disease followed in our institution, and with the precious imaging support of 60 other studies from obtained at the department of Radiology, Policlinica Vigo (POVISA), executed between 2009 and 2012. We describe the technique and present the spectrum of classical MR enterography findings in Crohn's disease:

Patterns of mural contrast enhancement (and clinical activity of the disease), wall thickening and edema of intestine loops, perienteric inflammation (fibrofatty proliferation, mesenteric hypervascularity and lymphadenopathy), signs of long-term Crohn's Disease and complications such as fistula and sinus formation, abscesses, strictures and bowel obstruction.

Technique

Enteroclysis is better but cumbersome, in particular envolves radiation for nasojejunal tube placement. In most instances enterography is prefered because it is less time consuming, patient acceptance is better and luminal distension is also good.

In fact, bowel distention is the key for an adequate examination. It is important to provide us an accurate interpretation because collapsed bowel loops can hide lesions and give the false appearance of wall thickening, abscess or enlarged lymph nodes.
Fig. 1: Normal terminal ileum. a) Coronal Fat Sat True FISP, b) Coronal HASTE, c) Coronal True FISP, d) Coronal enhanced T1 VIBE, depicting a normal non distended terminal ileum. This can easily be mistaken for a thickened terminal ileum with signs of activity, specially if we attent on bowel wall thickness in True FISP (red arrow) and the relative hyperenhancement in T1 VIBE sequences (green arrow).

References: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

Luminal contrast

For bowel distension oral constrast agentes are used. They are categorized according to effects on T1 and T2 weighting

There are three types of oral contrast agents

- **Negative** - good for looking at bowell Wall
- **Positive** - not of much use with inahbility to assess adjacent mucosa.
• **Biphasic (low T1, high T2)**, - It is used most of times. They are hyperosmolar and prevent absorption. Side effects being diarrhoea and flatulence, all patients should be warned of this possibility.

![Fig. 2: Different kinds of oral contrast agents](image)

**References:** Jose Tiago Soares - Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

In our practice we use a **biphasic contrast agent** - Polyethylene glycol which allows the assessment of fold thickness on T2 weighted sequences due to high contrast between wall (low T2) and lumen (high T2), while not detracting from abnormal enhancement seen on T1 sequences.
**Fig. 3:** Luminal distension of the small bowel (arrow) is important to provide an accurate interpretation of the anatomic and morphologic changes. Coronal T2-weighted fat suppressed sequence (HASTE) shows the presence of high T2 signal intensity of the bowel lumen due to the presence of a biphasic oral contrast agent (arrow), allowing better depiction of the bowel wall (low T2 signal intensity), specially when it is thickened (*).

**References:** Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

**Protocol**

Patients should undergo 5 days of low residue diet and fast 6 hours before the procedure.

Luminal distension is achieved by administration of a large amount of enteric contrast agent - Polyethylene glycol (Klean Prep 69g - Norgine) immediately before the examination, over one and half hours.

- Patients are asked to drink 1L in the first 15 minutes and then 500 mL in the next 10 minutes. Before entering the room they are asked to drink another 200 mL.

- Although we aim for 1.5-2 L in total, some patients cannot tolerate this volume and reasonable studies may still be obtained with as little as 500 mL.
**Patient positioning**

The patient is usually imaged in **prone position**, this way we reduce motion artifacts and allow compression and separation of small bowel loops with better luminal distension.

**Supine position** may be required in patients with stomas and abdominal wall fistulas.

**Timing of scan**

Remember, the key is distension, so:

If rapid transit is suspected clinically, initial scan at 20 min.

Most patients can be scanned at 40-60 min

If jejunal disease is suspected, scan earlier at 20 min.

Effective scanner use could be scanning at 40 min as a standard protocol.

**Fig. 4**: a) Coronal FISP, at 20 minutes, oral contrast has insufficiently reached the terminal ileum as it depicts a thick appearance of its bowel wall (yellow arrow). Further
delay of 20 minutes coronal FISP- b) and HASTE - c) shows good distension of the terminal ileum, and normal thickness of bowel wall (orange arrows). No abnormality was noted on this study.

**References:** Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

**Sequences**

In our institution, MR imaging is performed with a 1.5 T system using large body coil to get sufficient resolution and field of view.

**STEP 1:** Coronal **THICK SLAB T2-WEIGHTED HASTE** sequence (I)

![Figure 5: HASTE sequences](image)

**References:** Jose Tiago Soares

- to check if contrast has reached the terminal ileum/right colon and if there is adequate bowel distension

- if there is no contrast in the right colon consider further oral contrast and rescan in further 15-30 mins

**HASTE Sequence (I)**

**Half-Fourier acquisition single-shot turbo-spin echo**
A rapid sequence taking approximately a sec for each slice. It returns T2 weighted images.

A fast scan giving a good resolution image which allows rapid overview of entire abdomen, also providing information about distension.

MRCP style sequence

**STEP 2:** Coronal, axial and sagittal **BALANCED GRADIENT-ECHO T2-WEIGHTED (True FISP)** sequences

![True FISP Sequence](image)

**Fig. 6:** True FISP Sequence

**References:** Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

- assessment of distension and overview of disease

**True FISP Sequence**

**True** Fast Imaging with **Steady-state** Precession imaging

Resistant to flow and motion artefact, returns high fluid-tissue contrast with T2 weighted images.

Fast scan giving a good resolution image which allows rapid overview of entire abdomen, also providing information about distension.

Indicated to access small bowel lumen, mesenteric adenopathy, mesenteric vascularity and dynamic bowell loop information. *(figs 27,28,29)*

**Caution!!** Chemical shift artefact (black line) is present, therefore this sequence is not recommended to assess bowel wall thickness. *(fig.7)*
Fig. 7: Coronal HASTE (a) and true FISP (b) sequences are shown. There is thickening of a segment of ileum. It shows chemical shift on FISP in keeping with fat deposition. Also note FISP is poorer in assessing bowel wall in comparison to HASTE, although it is better to assess vascularity.

References: Department of Radiology, Policlínica Vigo, S.A (POVISA) , Vigo 2012

STEP 3: CINE TRUE FISP sequences in the coronal or sagittal planes oriented to the affected segments - Fig 8

- To assess bowel motility, distinction between fixed and transitory segments of narrowing and segmental dilatation

- To differentiate between incomplete luminal distension simulating wall thickening and the presence of activite disease.

STEP 4: SPASMOLYTIC administration - Glucagon (1 mg)

- Bowel peristalsis can cause motion artifacts and blurring.

- To avoid it, an antiperistaltic drug is administered , 1 mg of Glucagon
(Glucagen; Novo Nordisk, Bagsvaerd, Denmark) i.m or i.v after cine imaging and before administering intravenous contrast material to eliminate bowel movement and contraction.

- In diabetic patients hyoscine butylbromide (Buscopan; Boehringer Ingelheim, Ingelheim, Germany) is used instead (20-40 mg intravenous).

**STEP 5:** Coronal and axial **THIN SLAB T2-WEIGHTED HASTE** sequence (II)

**Fig. 9:** Haste sequences.

**References:** Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

**HASTE Sequence (II)**

...

Useful for assessing focal wall thickening, fold pattern changes and ulceration.

Susceptible to flow and motion artefacts from peristalsis (therefore prior glucagon).

**STEP 6:** Coronal and axial **FAT-SATURATED HASTE** sequences
Fig. 10: Fat Sat HASTE sequence

References: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

- When combined with (previous) T2-Weighted HASTE sequences demonstrates:

  • Wall (red arrow) or mesenteric (green arrow) edema, (green arrow) indicating active inflammation
  • Differentiation between fatty infiltration of the bowel wall (Fat halo) and bowel wall edema (Water Halo) - figs. 31, 32
  • Differentiation between mesenteric edema and fluid from creeping mesenteric fat.

- Useful when gadolinium is not appropriate

STEP 7: DIFFUSION WEIGHTED IMAGING (DWI)
**Fig. 11:** Diffusion Weighted Imaging sequence

**References:** Department of Radiology, Policlinica Vigo, S.A (POVISA), Vigo 2012

- Fast and sensitive sequence, depicting bowel wall hiperintensity as we elevate the value of b (b=0, 50, 300, 800 sec/mm²).

- This hiperintensity areas traduce restriction to diffusion weighted imaging, and in this setting, areas of higher probability of corresponding to inflammatory activity.

**STEP 8:** Baseline 3D Coronal T1 (VIBE) WITH FAT SUPRESSION - pre gadolinium

![Baseline 3D Coronal T1 (VIBE) Fat Suppression](image)

**Fig. 12:** Baseline 3D Coronal T1 (VIBE) Fat Sat

**References:** Department of Radiology, Policlinica Vigo, S.A (POVISA), Vigo 2012

- Comparative study with the following pos contrast sequence - to assess enhancement

**THRIVE (VIBE) Sequence**

**Volumetric Interpolated Breath-hold Examination**

A quick T1 weighted scan. It helps in assessing for post contrast enhancement. It gives information in regard to bowel wall enhancement pattern, fistula and abscesses.
**STEP 9: GADOLINIUM-BASED CONTRAST** (Gd-DOTA 0.1 mmol/kg) - with power injection at a flow rate of 1mL/sec followed by injection of 30 mL of saline (except in patients with contraindications against intravenous gadolinium)

**STEP 10: 3D Coronal T1 (VIBE) FAT SAT** - post gadolinium with 30 and 90 seconds delay

![Image](image1.png)

**Fig. 13**: 3D Coronal T1 (VIBE) Fat Sta - post gadolinium - 30 and 90 seconds delay

**References**: Department of Radiology, Policlínica Vigo, S.A (POVISA), Vigo 2012

- Assessment of the abdominal vasculature, mesenteric edema, lymph nodes, mural enhancement, fistulas, abscesses, sinus (green arrow), and extraintestinal abnormalities.

- Assessment of inflammatory lesion activity

**STEP 11 - 3D Axial T1 (VIBE) FAT SAT** - post gadolinium with > 120 seconds delay
Fig. 14: 3D Axial T1 (VIBE) Fat Sat - post gadolinium - > 120 seconds delay

References: Department of Radiology, Policlínica Vigo, S.A (POVISA), Vigo 2012

- Assessment of extraintestinal findings (lymph nodes, abscesses, fistulas, sinus...)

**NOTE**: If patients struggle with breath holding and keeping still, a the 3D T1 sequence can be replaced by a 2D T1W sequence, which is less susceptible to movement artefact even though it has reduced spatial resolution

The examination aims for a 30 minute total scan time.

**SPECTRUM OF FINDINGS IN MR ENTEROGRAPHY IN PATIENTS WITH CROHN’S DISEASE**

Crohn’s disease can be **active** and show **acute** alterations or can be **inactive** and present **chronic** fibrotic changes.

It’s common that the same affected segment of bowel contains both acute and chronic changes.

**1. ACTIVE DISEASE**

The affected bowel loops usually have a **thickened bowel wall** associated with signs of **acute inflammatory changes**.

*Thickened Bowel Wall*
- Is associated with active inflammation and the degree of thickening has been proven to be correlated with inflammatory activity

- More than 3 mm is significant but it is usually around 5-10 mm\(^{(2)}\)

- Wall thickening is best assessed on HASTE to avoid chemical shift artefact on True FISP sequences.

3 Thickening Patterns

1. Diffuse "Picket fence" fold thickening

![Fig. 15: (a), (b) - Coronal T1 (VIBE) FAT SAT - post gadolinium depicting diffusely thickened folds in keeping with "picket fence" appearance - c). Also of note the diffuse wall hyperenhancement traducing active disease. References: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT](attachment:fig15.png)

2. Distortion of folds due to ulceration
Fig. 16: a) Various types of ulcerations. b) Coronal HASTE, c) coronal HASTE Fat Sat, d) Sagital true FISP sequences show rose thorn ulceration of the lateral wall of ileum

References: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

3. Cobblestone mucosal pattern caused by longitudinal and transverse ulceration

- Best assessed on True FISP as Fast spin-echo T2-weighted images are particularly prone to intraluminal flow artifact

Fig. 17: Cobblestone. a) Coronal FISP and showing nodular wall thickening in keeping with cobblestone appearance as seen in a surgical resected specimen - c). b) Post contrast coronal VIBE shows diffuse wall enhancement in keeping with active disease.

References: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT
**Acute Inflammatory Changes**

1. Mucosal / submucosal edema

   - Hyperintensity of signal in bowel wall in T2 weighted images, specially in sequences with fat suppression **T2WI fat sat**

**Fig. 18**: Axial fat-saturated HASTE sequence demonstrates edema of the wall of a segment of small bowel (arrow) and free fluid (*).

**References**: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

   - Restriction to diffusion in DWI
Fig. 19: a) Axial Pre contrast T1 VIBE and b), c) Axial 30s and 90 s post contrast T1 VIBE show a thickened segment of ilium with intense contrast enhancement indicating activity. d), e), f) Axial DWI (b-0, b-100, b-800) show restriction to diffusion, confirming the previous findings. Of notice is a thin hyperintense line in the bowel wall (b, c, d, e, f) corresponding to a transmural ulcer originating an incipient sinus tract.

References: Department of Radiology, Policlinica Vigo, S.A (POVISA) , Vigo 2012

2. Mucosal ulceration

- Irregularity of the mucosa and thin lines with high signal intensity within the thickened bowel wall on T2WI HASTE and ENHANCED T1 (VIBE) Fat Sat sequences.

- Although difficult to assess with MR-E as it is highly dependent on the quality of luminal distention, this very superficial irregularity represents mucosal ulceration.

- Best accessed on HASTE sequences.

- Can be superficial, longitudinal or transmural, specially the transmural ones, support the diagnosis. transmural ulcer can progress to bowel perforation or even fistulas.

- Fluoroscopy and endoscopy are better assessing this.
Fig. 20: Superficial ulcers of bowel wall. a) coronal True FISP FAT SAT depicting a pathologic small bowel loop showing wall thickening and transversal ulcer (arrow). b) Same aspect in coronal 3D GRE T1WI fatsat (60 S after iv contrast injection), transversal ulcer (arrow) and stratified enhancement. c) T2WI HASTE. There is marked irregularity of the mucosa with longitudinal and transmural stripes in relation with superficial and profound ulceration (green arrows).

References: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

3. Mucosal hyperemia

- **Increased enhancement** in bowel wall relative to adjacent loops (especially if transmural or stratified pattern of enhancement)
• May be one of the earliest signs of inflammatory active disease and can occur without bowel wall thickening

• The intensity of enhancement of the bowel wall correlates well with the degree of activity of the disease.

• It’s better seen on T1-weighted fat suppressed sequences, and the comparison with adjacent loops should be made with loops equidistant from centre of field, to avoid field inhomogeneity.

3 patterns of enhancement:

1. **Stratified Contrast Enhancement** - In acute inflammation there is an inner and outer enhancing rings, "layered appearance", due to hyperemic mucosa and serosa, and poor submucosal enhancement (submucosal edema).

2. **Transmural Contrast Enhancemnet** - Represents diffuse wall enhancement due to severity of the inflammation.

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**Fig. 21:** Stratified Contrast Enhancement

**References:** Jose Tiago Soares - Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT
Fig. 22: Transmural Contrast Enhancement.

References: Jose Tiago Soares - Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

3. **Low level non-homogenous Contrast Enhancement** -

This is seen in fibrosis and suggests chronicity.
4. Mesenteric edema

- Intermediate to high signal intensity of the mesenteric fat tissue in fat sat T2WI
- Can occur with activity of the disease, resulting of perienteric inflammation and mesenteric edema
- Increased enhancement of the mesenteric fat is also a sign of active disease
- Fat Sat HASTE is most useful

![Fig. 23: Low level non-homogenous Contrast Enhancement](image)

References: Jose Tiago Soares - Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

5. Skip lesions

- Characteristic in Crohn's disease.

![Fig. 24: Mesenteric edema](image)

References: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT
Fig. 25: Skip lesions. The coronal T2 HASTE - a), T2 HAST FAT SAT -b) , True FISP - c) and post contrast fat sat VIBE - d) sequences show stricturing intermedium jejunal disease on the left and mural stratification enhancement pattern in the terminal ileum.

References: Department of Radiology, Policlínica Vigo, S.A (POVISA) , Vigo 2012

6. Reactive peritoneal fluid

- Can appear as free fluid without loculation, encapsulation or mass effect and with high signal intensity on T2-weighted sequences.

7. Comb sign

- Increased mesenteric vascularity adjacent to the inflamed bowel segments and engorgement of the vasa recta - "comb sign"
- Can be seen as short parallel lines with low signal intensity on true FISP sequences and high signal intensity on Post contrast T1 (VIBE) sequences.
Fig. 27: Coronal fat-suppressed T1-weighted sequence a) before and b) after administration of intravenous gadolinium shows enlarged lymph nodes with high signal intensity (arrow). A thickened small bowel wall segment is also present (*).

References: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

8. Mesenteric lymphadenopathy

- Usually indicative of active inflammation, ranging from 3 to 8 mm.
- MR enterography shows enlarged mesenteric lymph nodes with homogeneous hyperenhancement after administration of gadolinium.
- Edema of the lymph nodes can be demonstrated by fat saturated sequences.
- If the lymph nodes are larger than 10 mm, neoplasms (lymphoma and carcinoma) need to be excluded. If there are non enhancing nodes think of necrotic caseating nodes - present in tuberculosis and, more rarely, in histoplasmosis.
Fig. 29: Coronal fat-suppressed T1-weighted sequence a) before and b) after administration of intravenous gadolinium shows enlarged lymph nodes with high signal intensity (arrow). A thickened small bowel wall segment is also present (*).

References: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

9. Creeping fat or fat wrapping

- Increased mesenteric fat (hypertrophy) producing a mass effect, manifesting as anatomic displacement of mesenteric vessels or surrounding abdominal viscera.

- Associated with long-standing disease and transmural inflammation

- It is frequently asymmetric, preferentially involving the mesenteric border of the bowel

- HASTE sequences demonstrate slightly decreased signal intensity of the fat adjacent to bowel segments affected by Crohn’s disease compared to normal fat.

- A very specific sign for Crohn disease
Fig. 28: Axial (A) and coronal (B) balanced gradient-echo T2-weighted (true FISP) sequences show fibrofatty proliferation of the mesentery with mass effect and separation of bowel loops (*).

References: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

Note:

Disease of the colon - Although MR enterography is focused in the small bowel, sometimes it can show active disease of the colon with hyperenhancement and mural thickening, similar to the changes previous described for the small bowel. However in the majority of patients the colon has not an adequate luminal distension and has colonic fecal residue impairing the study interpretation.
Fig. 30: Coronal (A) and axial (B) fat-suppressed T1-weighted sequence after administration of intravenous gadolinium shows hyperenhancement and mural thickening of the descendent colon (arrows) in a patient with Crohn disease. The "comb sign (*) is also present.

References: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

2. INACTIVE CHRONIC DISEASE

It is a long-term evolution subtype of Crohn's disease in which intestine loops have suffered from chronic inflammation and develop fibrosis. The affected bowel loops may have a **thickened bowel wall** without acute inflammatory changes presenting some signs of **chronicity**.

**Thickened bowel wall**

- > 3 mm is signficative although normally less exuberant than active disease
- mural stratification
- **Usually low to moderate signal intensity on T2-weighted images due to the fibrosis**

**Chronicity signs**

1. Fatty infiltration

- **Hyper intensity** of the bowel wall signal in **T2WI** sequences and **hypointensity** of the bowel wall signal in **T2WI fat suppressed**
• Generally, fat-saturated and non-fat-saturated T2-weighted HASTE sequences are required to differentiate fat from wall edema, with the latter demonstrating persistent high signal intensity with both sequences, whereas fat saturation will reduce wall signal intensity that is due to fat.

• Gradient-echo (FISP) sequences demonstrate chemical shift artifact in the presence of intramural fat

• Caution as this fat deposition in bowel wall may also occur in healthy individuals, particularly in association with obesity

As we’ve seen earlier, in active disease, the edematous bowel wall also presents hiperintense in T2WI. How to differentiate this alteration from fatty infiltration?

**Acute Wall edema vs. Chronic Mural fat deposition:**

As both show high signal intensity at T2-weighted sequences, we perform T2 HASTE and T2 Fat Sat HASTE

Fat sat eliminates high signal from mural fat deposition in chronic disease whereas edema will show persistent high signal.
**Fig. 31:** Water halo. Axial and coronal HASTE a), c) and Fat sat HASTE b), d) - shows thickened ileum with bowel wall edema (yellow arrows) seen as persistent high signal within the bowel wall on Fat sat images (red arrows).

*References:* Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT
Fig. 32: Fat halo - Coronal section of a thickened ileum loop. There is high signal bowel wall (yellow arrow) on HASTE - a), suppressing to a low signal (red arrow) on Fat Sat HASTE- b) confirming mural fat deposition.

References: Department of Radiology, Policlínica Vigo, S.A (POVISA), Vigo 2012

2. Faint and inhomogenous wall enhancement

- Poor inhomogeneous or no enhancement on T1-weighted fat suppressed sequences (absence of active disease - no mural edema).
**Fig. 33:** Focal thickening of ileum bowell wall (red arrows) on FISP - a); T1 Fat sat pre contrast - b); 40 /90 seconds post contrast VIBE - c) / d). There is no hyperenhancement relative to other bowel loops (orange arrow) - this is inactive disease.

**References:** Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT
**Fig. 34:** Chronic thickening of ileum bowel wall with poor enhancement (arrow), a finding that suggests chronic disease. a) Coronal HASTE, b) Coronal Fat Sat HASTE, c) Coronal Pré contrast T1-weighted VIBE, d) Coronal contrast enhanced T1-weighted VIBE.

*References:* Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

3. **Pseudodiverticula and Pseudopolyposis**
• Caused by asymmetric bowel fibrosis and shortening of mesenteric wall, with relative sparing of the antimesenteric border.

• Fibrosis and shortening of the diseased mesenteric wall leads to apparent dilatation of the opposing normal bowel wall.

• It involves all three bowel wall layers form the sacculation (in contrast to colonic diverticular disease).

• Pseudodiverticula can manifest on fat-suppressed T2-weighted sequences with intermediate signal intensity resulting from mesenteric edema and suffer enhancement after administration of gadolinium.

• Typical finding of a fibrotic-stenotic subtype of Crohn’s Disease.

Fig. 35: Pseudodiverticula and Pseudoploysis - The nodular terminal ileum post-surgery, depicting multiple pseudodiverticula (red arrows) and a pseudoploy (orange arrows) on coronal HASTE - a), true FISP b), and post contrast axial VIBE sequences - c).

References: Department of Radiology, Policlinica Vigo, S.A (POVISA), Vigo 2012

4. Stricture formation

• With time, chronic inflammation within the bowel wall can progress to bowel wall fibrosis and cause fixed narrow bowel segments (strictures).

• It is present when there is a difference of at least 10% in bowel lumen. It is called functional when the difference is >30%.

• In the presence of a stricture, bowel obstruction can occur and displays dilated (more than 3 cm) bowel loops proximal to the stricture.

• It has many differentials by itself.
Fig. 36: Strictures. a) Coronal contrast enhanced T1 VIBE (and detail of Coronal HASTE), showing a large segment stricture affecting the terminal ileum. b) Coronal contrast enhanced T1 VIBE representing a stricture (arrow) affecting an anastomosed segment of ileum and subsequent upstream dilatation. c) Coronal true FISP shows a stricture segment of small bowel (arrow).

References: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT
Fig. 8: CINE True FISP sequence clearly demonstrating a strictured terminal ileum loop without any peristaltic movement, unlike the rest of the bowel segments.  

**References:** Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

5. **Small lymph nodes that do not enhance**  
   - can be seen in chronic inactive Crohn disease.
It's important to remember that acute and chronic signs of the disease may coexist!!

![Fig. 37: Active and chronic signs of Crohn's disease. a,b) Axial Post contrast enhanced T1 VIBE demonstrating thickness of distinct segments of small bowel showing different patterns of enhancement, the terminal ileum showing marked stratified enhancement representing signs of activity (red arrow). The other proximal thickened ileal segment (yellow arrow) demonstrates a faint inhomogenous wall enhancement compatible with a chronic fibrotic bowel segment.](image)

References: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

3. COMPLICATIONS - PENETRATING DISEASE AND BOWEL OBSTRUCTION

Deep ulceration formation can cause transmural inflammation, sinus tract and fistula formation.

1. Fistulas

- Fistulas can be entero-enteric, entero-colonic, entero-vesical, entero-vaginal or entero-cutaneous amongst others. Associated inflammatory signs indicate activity of the fistula.
- At T2-weighted sequences they manifest as high signal intensity tubular tracts between bowel loops
- Strong peripheral enhancement after gadolinium administration on contrast-enhanced T1-weighted sequences.
- Fistulas in the perineal region are common in Crohn disease.
- Dynamic fluoroscopy is better in assessment these instances when suspected.
**Fig. 38:** Enterocolic fistula. (a,b) Coronal FISP (a,b) images show an iliocolic anastomised patient with a thickened segment of ileum (red arrow) adjacent to the sigmoid cólon (green arrow). (c) Coronal VIBE shows the intimal contact between the ileum /ascending cólon and the sigmoid cólon (*). (d) Coronal VIBE and (c) axial VIBE , better depict a complex bowel network (orange arrow) and an enhancing tract (yellow arrow) connecting the ileum/ascending colon to the sigmoid cólon.

**References:** Department of Radiology, Policlínica Vigo, S.A (POVISA) , Vigo 2012
- **Enteroenteric fistulas** can form a complex network between adherent small bowel loops and have a stellate appearance (fibrotic and desmoplastic reaction), with multiple tracts, sharp angulation and bowel loops radiating from a central point, on contrast-enhance MR sequences.

**Fig. 39**: Coronal HASTE (a), FISP (b) and T1 VIBE after administration of intravenous gadolinium show a complex network of adherent small bowel loops that radiate from a central point, suggesting the presence of enteroenteric fistulas. In the right hipocondrious there is a skip of more normal bowel between two strictures (blue arrows).

**References**: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT
**Fig. 44:** Abcess and entero-vesical fistulas. (a, b) Coronal HASTE show a complex network of adherent thickened small bowel loops (red arrow) converging into a fluid collection (abcess) (*) adjacent to the antero-superior vesical wall. (d,e) Axial HASTE depict the before mentioned complex bowel network comunicating with the supravesical abscess. (c,e) Sagital and Coronal enhanced T1 VIBE clearly demonstrating the enhancing supra vesical abcess and comunicication with the vesical lumen.

**References:** Department of Radiology, Policlínica Vigo, S.A (POVISA) , Vigo 2012

2. Sinus tract

- Blind-ending fistulas that arise from transmural ulcers, penetrating the bowel wall but not reaching a hollow organ.

- Similar to fistulas on MR or may appear as nodular irregularities or linear spiculated structures and sometimes can be associated with abscesses.
Fig. 40: Sinus Tract. a) Coronal Pre contrast T1 VIBE ; b,c) Coronal 30 and 90 s post contrast enhanced T1 VIBE depict an early contrast enhancing transmural ulcer penetrating the bowel wall into the peritoneal cavity (yellow arrow), forming a blind ending tract, not fully reaching the adjacent bowel.

References: Department of Radiology, Policlinica Vigo, S.A (POVISA), Vigo 2012

3. Abscesses

- Well-defined, fluid collections that can occur in the small bowel mesentery, psoas muscle, abdominal wall or around the anus.
- High signal intensity on T2-weighted images, low signal intensity on fat-suppressed T1-weighted images
- Best identified on contrast-enhanced T1-weighted sequences because this sequence displays the intense rimlike enhancement of the fluid collection.
- Abscess contents are heterogeneous and may contain gas (difficult to see at MR studies.)
**Fig. 41**: Coronal (a) and (b) and axial (c) fat-suppressed T1-weighted sequence before (a) and after administration (b and c) of intravenous gadolinium shows intense enhancement of a heterogeneous fluid collection (arrow) that was proved to be an abscess as shown in contrast-enhanced CT scan performed two days after (arrow in D) in a patient with Crohn's disease.

**References:** Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

4. Peritoneal adhesions

- Inflammation of the mesentery can cause adhesions (common in Crohn disease) which may lead to bowel obstruction.
• Should be distinguished from fistulas as adhesions are thinner and fibrotic and can be seen as low-signal intensity bands coursing the mesenteric fat on T2-weighted sequences and enhance later than fistulas.

• Sometimes is not possible to see the adhesions but they can be inferred as they can cause kinking, bowel tethering and obstruction of bowel segments and there is an abrupt narrowing in luminal diameter without apparent cause at the point of transition.

**Fig. 42**: Adhesion/ Fibrosed fistulous tract (a) Coronal True FISP and (b) Coronal HASTE showing a fistulous tract establishing a communication between two different small bowel loops. (c) Coronal T1 VIBE pré-contrast enhancement, and (d) T1 VIBE
post-contrast enhancement revealing no contrast enhancement of the fistulous tract, signs of chronic inactive disease.

**References:** Department of Radiology, Policlínica Vigo, S.A (POVISA), Vigo 2012

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**Fig. 43:** Bowel loops adhesions (a) 3D Coronal T2 HASTE Fat Sat. (b) T1 VIBE Fat Sat post-contrast enhancement. There are several small bowel loops showing strictured bowel lumen (a), signs of thickened bowel wall and some loops appearing to be close together ("\*"), rising the suspicion of intestinal adhesions. There is an inhomogeneous contrast enhancement suggesting chronic disease, but in fact, this was a case of active entero-vesical fistulating disease (not shown), also perceptible from mass effect and separation of bowel loops caused by hypertrophy of the mesentery fat, a specific sign for active Crohn's disease.

**References:** Department of Radiology, Policlínica Vigo, S.A (POVISA), Vigo 2012

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5. **Bowel obstruction**

- May result from active disease or fibrostenotic disease.
- With fibrostenotic disease a fixed narrowing is commonly seen, particularly in the terminal ileum.

6. **Adenocarcinoma**

- Patients with Crohn's disease have increased risk of developing adenocarcinoma and lymphoma of the bowel.
- **Adenocarcinoma** more commonly appears as a **stricture** sometimes associated with a **nodular mass** and can be difficult to distinguish from inflammatory strictures. Bowel obstruction can be the manifestation of a neoplasm.
• Asymmetric mural thickening, mesenteric infiltration and lymphadenopathy are some features that suggest malignancy.

• Lymphoma usually manifest as multifocal nodular areas and strictures.

ANY QUESTIONS?

Fig. 45: Active disease - T1 VIBE contrast enhanced sequence depicting a large strictured segment of small bowel loop with avid contrast enhancement.

References: Radiology, Centro Hosp. Vila Nova de Gaia - Vila Nova de Gaia/PT

Images for this section:
Fig. 1: Normal terminal ileum. a) Coronal Fat Sat True FISP, b) Coronal HASTE, c) Coronal True FISP, d) Coronal enhanced T1 VIBE, depicting a normal non distended terminal ileum. This can easily be mistaken for a thickened terminal ileum with signs of activity, especially if we attend on bowel wall thickness in True FISP (red arrow) and the relative hyperenhancement in T1 VIBE sequences (green arrow).
Fig. 2: Different kinds of oral contrast agents
**Fig. 3:** Luminal distension of the small bowel (arrow) is important to provide an accurate interpretation of the anatomic and morphologic changes. Coronal T2-weighted fat suppressed sequence (HASTE) shows the presence of high T2 signal intensity of the bowel lumen due to the presence of a biphasic oral contrast agent (arrow), allowing better depiction of the bowel wall (low T2 signal intensity), specially when it is thickened (*).

**Fig. 4:** a) Coronal FISP, at 20 minutes, oral contrast has insufficiently reached the terminal ileum as it depicts a thick appearance of its bowel wall (yellow arrow). Further delay of 20 minutes coronal FISP- b) and HASTE - c) shows good distension of the terminal ileum, and normal thickness of bowel wall (orange arrows). No abnormality was noted on this study.
Fig. 7: Coronal HASTE (a) and true FISP (b) sequences are shown. There is thickening of a segment of ileum. It shows chemical shift on FISP in keeping with fat deposition. Also note FISP is poorer in assessing bowel wall in comparison to HASTE, although it is better to assess vascularity.
**Fig. 8:** CINE True FISP sequence clearly demonstrating a strictured terminal ileum loop without any peristaltic movement, unlike the rest of the bowel segments.

![CINE True FISP sequence](image)

**Fig. 15:** (a), (b) - Coronal T1 (VIBE) FAT SAT - post gadolinium depicting diffusely thickened folds in keeping with "picket fence" appearance - c). Also of note the diffuse wall hyperenhancement traducing active disease.

![Coronal T1 (VIBE) FAT SAT](image)

**Fig. 16:** a) Various types of ulcerations. b) Coronal HASTE, c) coronal HASTE Fat Sat, d) Sagital true FISP sequences show rose thorn ulceration of the lateral wall of ileum.
**Fig. 17:** Cobblestone. a) Coronal FISP and showing nodular wall thickening in keeping with cobblestone appearance as seen in a surgical resected specimen - c). b) Post contrast coronal VIBE shows diffuse wall enhancement in keeping with active disease.

**Fig. 18:** Axial fat-saturated HASTE sequence demonstrates edema of the wall of a segment of small bowel (arrow) and free fluid (*).
**Fig. 19:** a) Axial Pre contrast T1 VIBE and b), c) Axial 30s and 90 s post contrast T1 VIBE show a thickened segment of ileum with intense contrast enhancement indicating activity. d), e), f) Axial DWI (b-0, b-100, b-800) show restriction to diffusion, confirming the previous findings. Of notice is a thin hyperintense line in the bowel wall (b, c, d, e, f) corresponding to a transmural ulcer originating an incipient sinus tract.
**Fig. 20:** Superficial ulcers of bowel wall. a) coronal True FISP FAT SAT depicting a pathologic small bowel loop showing wall thickening and transversal ulcer (arrow). b) Same aspect in coronal 3D GRE T1WI fatsat (60 S after iv contrast injection), transversal ulcer (arrow) and stratified enhancement. c) T2WI HASTE. There is marked irregularity of the mucosa with longitudinal and transmural stripes in relation with superficial and profound ulceration (green arrows).
Fig. 21: Stratified Contrast Enhancement

Fig. 22: Transmural Contrast Enhancement.
Fig. 23: Low level non-homogenous Contrast Enhancement

Fig. 24: Mesenteric edema. a) Axial fat-suppressed T1-weighted sequence after administration of intravenous gadolinium shows small bowel wall thickening (arrow) and increased enhancement of the mesenteric fat (*) suggesting active disease. b) Axial fat-suppressed T2-weighted sequence shows intermediate signal of the mesenteric fat indicating mesenteric edema (*).
Fig. 25: Skip lesions. The coronal T2 HASTE - a), T2 HAST FAT SAT - b), True FISP - c) and post contrast fat sat VIBE - d) sequences show stricturing intermedium jejunal disease on the left and mural stratification enhancement pattern in the terminal ileum.
Fig. 26: Axial fat-saturated HASTE sequence demonstrates edema of the wall of a segment of small bowel (arrow) and free fluid (*).
**Fig. 27:** Coronal fat-suppressed T1-weighted sequence a) before and b) after administration of intravenous gadolinium shows enlarged lymph nodes with high signal intensity (arrow). A thickened small bowel wall segment is also present (*).

**Fig. 28:** Axial (A) and coronal (B) balanced gradient-echo T2-weighted (true FISP) sequences show fibrofatty proliferation of the mesentery with mass effect and separation of bowel loops (*).
Fig. 30: Coronal (A) and axial (B) fat-suppressed T1-weighted sequence after administration of intravenous gadolinium shows hyperenhancement and mural thickening of the descendent colon (arrows) in a patient with Crohn disease. The "comb sign (*) is also present.
Fig. 31: Water halo. Axial and coronal HASTE a), c) and Fat sat HASTE b), d) - shows thickened ileum with bowel wall edema (yellow arrows) seen as persistent high signal within the bowel wall on Fat sat images (red arrows).
**Fig. 32:** Fat halo - Coronal section of a thickened ileum loop. There is high signal bowel wall (yellow arrow) on HASTE - a), suppressing to a low signal (red arrow) on Fat Sat HASTE- b) confirming mural fat deposition.
Fig. 33: Focal thickening of ileum bowell wall (red arrows) on FISP - a); T1 Fat sat pre contrast - b) ; 40 /90 seconds post contrast VIBE - c) / d). There is no hyperenhancement relative to other bowel loops (orange arrow) - this is inactive disease.
Fig. 34: Chronic thickening of ileum bowell wall with poor enhancement (arrow), a finding that suggests chronic disease. a) Coronal HASTE, b) Coronal Fat Sat HASTE, c) Coronal Pré contrast T1-weighted VIBE, d) Coronal contrast enhanced T1-weighted VIBE.
**Fig. 35:** Pseudodiverticula and Pseudopolyposis - The nodular terminal ileum post-surgery, depicting multiple pseudodiverticula (red arrows) and a pseudopolyp (orange arrows) on coronal HASTE - a), true FISP b), and post contrast axial VIBE sequences - c).

**Fig. 36:** Strictures. a) Coronal contrast enhanced T1 VIBE (and detail of Coronal HASTE), showing a large segment stricture affecting the terminal ileum. b) Coronal contrast enhanced T1 VIBE representing a stricture (arrow) affecting an anastomosed segment of ileum and subsequent upstream dilatation. c) Coronal true FISP shows a stricture segment of small bowel (arrow).
**Fig. 37:** Active and chronic signs of Crohn's disease. a,b) Axial Post contrast enhanced T1 VIBE demonstrating thickness of distinct segments of small bowel showing different patterns of enhancement, the terminal ileum showing marked stratified enhancement representing signs of activity (red arrow). The other proximal thickened ileal segment (yellow arrow) demonstrates a faint inhomogenous wall enhancement compatible with a chronic fibrotic bowel segment.
**Fig. 41:** Coronal (a) and (b) and axial (c) fat-suppressed T1-weighted sequence before (a) and after administration (b and c) of intravenous gadolinium shows intense enhancement of a heterogeneous fluid collection (arrow) that was proved to be an abscess as shown in contrast-enhanced CT scan performed two days after (arrow in D) in a patient with Crohn's disease.
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**Fig. 39:** Coronal HASTE (a), FISP (b) and T1 VIBE after administration of intravenous gadolinium show a complex network of adherent small bowel loops that radiate from a central point, suggesting the presence of enteroenteric fistulas. In the right hipocondrious there is a skip of more normal bowel between two strictures (blue arrows).
Fig. 38: Enterocolic fistula. (a,b) Coronal FISP (a,b) images show an iliocolic anastomised patient with a thickened segment of ileum (red arrow) adjacent to the sigmoid cólon (green arrow). (c) Coronal VIBE shows the intimal contact between the ileum /ascending cólon and the sigmoid cólon (*). (d) Coronal VIBE and (c) axial VIBE, better depict a complex bowel network (orange arrow) and an enhancing tract (yellow arrow) connecting the ileum/ascending colon to the sigmoid cólon.
Fig. 45: Active disease - T1 VIBE contrast enhanced sequence depicting a large strictured segment of small bowel loop with avid contrast enhancement.
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Fig. 44: Abscess and entero-vesical fistulas. (a, b) Coronal HASTE show a complex network of adherent thickened small bowel loops (red arrow) converging into a fluid collection (abscess) (*) adjacent to the antero-superior vesical wall. (d,e) Axial HASTE depict the before mentioned complex bowel network communicating with the supravesical abscess. (c,e) Sagital and Coronal enhanced T1 VIBE clearly demonstrating the enhancing supra vesical abscess and communication with the vesical lumen.
Conclusion

MR enterography is a successful tool in the evaluation of patients with Crohn’s disease. It allows evaluation of intra and extra-enteric manifestations of the disease with the advantage of avoiding ionizing radiation, playing an important role in the diagnosis and clinical management of these patients.

References


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