Learning objectives

The aim of our poster is to describe the frequent and infrequent imaging findings in Magnetic Resonance Enterography (MR-E) in patients with Crohn's Disease (CD).
Background

Crohn's disease (CD) is a chronic inflammatory condition that belongs to the so-called inflammatory bowel diseases, together with ulcerative colitis and indeterminate colitis.

**Etiology:** The exact cause is not known, although several factors have been found to be related with its pathophysiology, such as genetic, immunological and environmental factors.

CD can affect any segment of the digestive tract from mouth to anus, but it most frequently affects small and large bowel. Terminal ileum is the commonest site of onset [1]. CD typically shows a segmental affection of the bowel, combining affected gut segments separated by spared ones. There can also be extra-intestinal affections, including osteo-articular, dermatological or hepato-biliary.

The onset of the disease usually occurs in the second and third decades of life [2].

**Pathology:** CD 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.

**Clinical course and management:** CD is a chronic condition with acute relapses. Acute and chronic lesions can coincide in time. Patients can present with a wide range of symptoms, including crampy abdominal pain and diarrhoea (with or without blood). The course of the disease may be complicated with intestinal fistulas, particularly after surgical intervention, abscesses or by bowel obstruction.

Management of CD 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 CD inflammatory activity. 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. Physical examination, acute phase reactants, endoscopy and biopsy, imaging tests and clinical indexes such as Crohn's Disease Activity Index (CDAI) and Harvey-Bradshaw are amongst the tools used to appraise CD activity.
Role of Magnetic Resonance enterography (MR-E): MR-E is technique which does not use ionising radiation and helps in diagnosing CD, provides information about the extent of the disease, degree of inflammation and possible complications, helps in classifying CD and aids to plan the surgery when needed.

Indications of MR-E in our centre

Absence of diagnosis after colono-ileoscopy with biopsy, in patients with suspicion of CD
Post-surgical relapse of CD
Acute relapse with suspicion of stricture and/or intestinal obstruction
Treatment failure
Suspicion of complications

Importance of MR-E in the management of CD has been therefore increasingly growing in recent years, thus it is important for radiologists to be familiar with the frequent and infrequent findings of CD in MR-E.
Material and Methods:

100 MR-E studies between 2010 and 2011 from patients with CD were reviewed. We studied imaging findings of CD such as the affected intestinal segments, presence of bowel stenosis and/or intestinal obstruction, mural thickening of intestine loops, signs of active inflammation of the bowel, patterns of intestine wall enhancement, presence of lymphadenopathies, intestinal wall ulcers, signs of long-term CD as well as secondary complications.

MR-E scan protocol in our institution:

In our institution MR-E is performed in patients after 5 days of low residue diet and 6-8 hours of fasting.

We use a 3% manitol solution as oral contrast media most of the times, although we have used polyethyleneglycol in certain cases. Patients should drink 1.5 L of this manitol solution in 30-40 minutes, and we wait other 45-50 minutes to begin the MR study.

We do use glucagon (1 mg subcutaneous, intramuscular o intravenous) as spasmolytic drug, except in diabetic patients. In these cases we use hyoscine butylbromide (20-40 mg intravenous).

MR-E is performed in high-field scanners (# 1 T) with surface multichannel coil, scanning from diaphragm to rectum when possible (at least from liver to urine bladder). Patients stay in supine position, holding their arms above their head.

Our MR-E scan protocol usually includes the following sequences:

- SSFSE (HASTE) T2 weighted images, coronal and axial planes (#5 mm), with and without fat suppression.

- FIESTA (True-FISP, b-FFE) coronal and axial planes (#5 mm).

- GRE T1 in-phase and out-of-phase, in coronal plane.
-Diffusion weighted images of the region of interest.

-3D GRE T1 with fat suppression, in coronal plane (3 mm). This includes a baseline acquisition and several sequences performed 30, 60 and 120 seconds after iv administration of gadolinium-based contrast (Gd-DOTA 0.1 mmol/kg). Another extra sequence 5-7 minutes after contrast injection is performed. Usually axial acquisitions are also performed.

The whole scanning time is around 30-35 min.

We do not usually perform dynamic CINE studies unless we want to accurately assess intestinal motility.

**Imaging Findings:**

CD has a variable clinical course. Maglintie et al [3] describe four subtypes that are actually more patterns of behaviour or stages rather than different varieties of the disease.

<table>
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-Active inflammatory disease.

The affected bowel loops appear to have a thickened wall with signs of acute inflammatory changes.

Acute inflammatory findings in bowel loops

<table>
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<th>Bowel wall thickening</th>
<th>Hyperintense wall signal in fat sat T2WI</th>
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<td>High signal intensity in bowel wall in DWI</td>
<td>Increased enhancement in bowel wall (especially if stratified pattern of enhancement)</td>
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Bowel wall thickening is associated with active inflammation [4, 5] (Figure 1). Thickened bowel wall greater than 4 mm has been related to CD [6]. The degree of thickening has proven to be correlated with CDAI [7].
The thickening of intestine wall can lead to luminal stenosis and secondary intestinal obstruction (Figure 1).

**Fig. 1**: Figure 1. Inflammatory stenosis with mural abscess and secondary intestinal obstruction. A. Coronal SSFSE T2WI. Small bowel obstruction secondary to a stenotic ileum loop (arrows). B. Coronal 3D GRE T1WI fatsat (60 s after iv contrast injection). The stenotic ileum loop shows mucosal enhancement and a mural abscess (small arrows), compatible with acute inflammatory changes.

**References**: Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES

Hyperintensity of signal in bowel wall in T2 weighted images, especially in sequences with fat suppression, indicates oedema which is a sign of acute inflammation [4, 5] (Figures 2 and 3).
**Fig. 2:** Figure 2. Acute inflammatory changes in distal ileum. A. Detail of axial SSFE T2WI. Distal ileum loop with thickened wall (arrow). B. Detail of axial SSFSE T2WI fatsat. The thickened wall has high signal intensity compatible with oedema (arrow). C. Detail of axial 3D GRE T1WI fatsat (60 s after iv contrast injection). The ileum loop shows increased mucosal enhancement. Stratified-pattern of enhancement (arrow). D. Detail of DWI (b=600). The loop has high signal intensity(arrow). These are findings suggesting acute inflammation.

**References:** Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES
Fig. 3: Figure 3. Bowel loop with acute inflammatory changes (thick arrow) vs bowel loop with chronic CD changes (thin arrow). A. Axial SSFSE T2WI. Two ileum loops (arrows) show slight thickening and high signal intensity of their walls. B. Axial GRE T1WI. The wall of the more anterior ileum loop shows low signal (thick arrow), while the wall of the posterior one (thin arrow) has high signal compatible with fatty submucosa infiltration, typical in chronic CD. C. Axial SSFSE T2WI fatsat. The anterior loop shows increased signal within its wall compatible with oedema (thick arrow). The posterior loop has less increased wall signal (thin arrow). D. DWI (b=600) The more anteriorly located loop shows clearly increased signal intensity compatible with acute inflammation (thick arrow) while the other one does not (thin arrow). Note the diffuse mesenteric fat hypertrophy in all sequences, typical finding of CD.

References: Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clínico San Carlos - Madrid/ES

High signal intensity in diffusion weighted imaging and restricted diffusion of the bowel wall has also been related to acute inflammation [8] (Figures 2 and 3).
Bowel wall increased enhancement indicates wall inflammation [4, 6]. The so-called stratified type of bowel enhancement (mucosal increased enhancement with submucosal oedema), has been related to acute inflammation [5, 9] (Figures 2 and 4).

Fig. 4: Figure 4. Stratified-type of enhancement and comb sign. A. Coronal FIESTA. An ileum loop near an ileo-colostomy is dilated, has wall thickening and shows prominence of mesentery vasculature. B. 3D GRE T1WI fatsat (120 s after iv contrast injection). The pathologic ileum loop has an increased mucosa enhancement (stratified-type of enhancement) and prominence of mesentery vasculature (comb sign), compatible with acute inflammatory changes.

References: Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES

Full-thickness hyperenhancement can represent transmural inflammation [10] (Figures 5 and 6) although fibrotic segments can show full-thickness delayed enhancement (Figure 16).
**Fig. 5:** Figure 5. Full-thickness wall hyperenhancement. A. Axial FIESTA. Ileum loop with thickened wall. B. Axial 3D GRE T1WI fatsat (120 s after iv contrast injection). The affected bowel loop shows increased full-thickness wall enhancement compatible with transmural acute inflammation.

**References:** Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES

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**Fig. 6:** Figure 6. Full-thickness wall hyperenhancement, stratified-type of enhancement and inflammatory pseudopolyps. Two Axial 3D GRE T1WI fatsat images (120 s after iv contrast injection) from different patients. A. Small bowel loop with thickened wall and full-thickness increased enhancement. There is also an inflammatory pseudopolyp (arrow). These findings are compatible with transmural acute inflammation. B. Small bowel loop showing wall thickening and mucosal hyperenhancement. There is also a prominence of the mesenteric vascularity and an inflammatory pseudopolyp (arrow). These findings are also compatible with acute inflammatory changes.

**References:** Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES

Other MR imaging findings in acute inflammation
Mesenteric prominent vascularity
(comb sign)

Reactive lymph nodes

Hyperintense signal of peri-intestinal fat in T2WI

Ascites

The so-called "comb sign", indicating ingurgitation and prominence of vessels in the mesenteric side of a bowel loop. It favours the diagnosis of acute bowel wall inflammation [4] (Figures 4 and 6). CD affects more frequently the mesenteric side of the bowel loop.

Reactive mesenteric enlarged lymph nodes are suggestive of active inflammatory process [11]. Local lymph nodes which are increased in number may also indicate local inflammation. Their enhancement has also been related to acute inflammation [12] (Figure 7).

Fig. 7: Figure 7. Reactive mesentery lymph nodes in a CD patient. A. Axial baseline 3D GRE T1WI fatsat showing multiple mesentery lymph nodes with reactive aspect. B. Axial 3D GRE T1WI fatsat (60 s after iv contrast injection). The lymph nodes are enhancing. These findings support acute inflammatory changes.

References: Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES

Hyperintensity of signal in T2WI with fat saturation in the intraabdominal fat surrounding a bowel loop is an indicator of acute inflammation [10] (especially if the loop has also acute inflammatory signs itself) (Figure 8).
**Fig. 8:** Figure 8. Bowel loops adhesions and acute inflammation of bowel wall and mesentery fat in T2WI fatsat. A. Coronal SSFSE T2WI. There are several small bowel loops showing wall thickening and appearing to be close together, rising the suspicion of intestinal adhesions. B. Coronal SSFSE T2WI fatsat. After fat saturation there is still increased signal in both the thickened bowel wall and the mesentery fat, compatible with oedema and acute inflammation. Note the hypertrophy of the mesentery fat in relation to CD. Note also the ascites in RLQ, which supports the diagnosis of acute inflammation.

**References:** Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES

The presence of ascites in an adequate context of acute bowel inflammation is a sign that supports mesenteric and/or peritoneal secondary irritation (Figure 8).

Presence of intestinal ulcers (superficial, longitudinal or transmural), specially the transmural ones, supports the diagnosis of CD [13, 14].

Although very superficial ulcers are difficult to assess with MR-E, some irregularity of the mucosa can be visualized (Figure 9).
**Fig. 9**: Figure 9. Superficial ulcers of bowel wall. Detail from 3D GRE T1WI fatsat (120 S after iv contrast injection), from the same patient as in figure 4. There is marked irregularity of the mucosa in relation with superficial ulceration.

**References**: Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES

Linear or longitudinal ulcers are almost pathognomonic of CD [15] and form the characteristic cobblestone-like pattern, more clearly visualized in fluoroscopy studies.
Transversal ulcers can be found in bowel loops of CD patients. Signs of activity and acute inflammation can be found. Transverse ulcers can progress towards the serosa and end up in a transmural ulcer, bowel perforation or even fistulas (Figure 10).

**Fig. 10:** Figure 10. Transversal ulcer. Detail from axial 3D GRE T1WI fatsat (60 s after iv contrast injection). There is a pathologic small bowel loop showing wall thickening and stratified enhancement with a transversal ulcer (arrows).

**References:** Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES

Pseudopolyps are remaining mucosal islands surrounded by ulcerated wall (Figure 6).

Mural abscesses can also be found in the intestine of patients with CD, especially those with acute inflammation (Figure 1). Their presence is a relative contraindication of anti-TNF alpha therapy [16].

**-Perforating-fistulating disease.**

It is characterized by deep wall transmural ulcers that might develop into fistulising tracts. Frequency of presentation of fistulas in CD patients through life can be up to 35%, and most of them develop in the perianal region [17].
Fistulas can be blind-ended, entero-enteric, entero-colonic, entero-vesical, entero-vaginal or entero-cutaneous amongst others. Associated inflammatory signs indicate activity of the fistula. (Figures 8, 11 and 12).

**Fig. 11**: Figure 11. Entero-enteric fistulas. Two axial 3D GRE T1WI fatasat (delayed after iv contrast injection) from different patients. A. Multiple entero-enteric fistulas between several ileum loops in pelvis. The stratified-type of enhancement shows that the fistulas are active. B. Entero-enteric fistula between two small bowel loops showing enhancement and thus meaning that it is active.

**References**: Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES
**Fig. 12**: Figure 12. Entero-cutaneous fistula. Axial 3D GRE T1WI fatsat (delayed after iv contrast injection). Multiple active entero-cutaneous fistulas and pro-peritoneal inflammatory changes (arrows).

**References**: Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES

Fistulas can lead to the formation of abdominal inflammatory masses and abscesses (Figure 13 and 14).
**Fig. 13**: Figure 13. Intra-abdominal abscess. A. Axial SSFSE T2WI and B. Axial 3D GRE T1WI fatsat (delayed after iv contrast injection). There is an intra-abdominal collection (arrows) with air-fluid level, thick and enhancing wall, surrounded by inflammatory changes in mesentery fat and next to a bowel loop. Compatible with abscess.

**References**: Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES

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**Fig. 14**: Figure 14. Pelvic abscess. A. Coronal SSFSE T2WI and B. Coronal 3D GRE T1WI fatsat (delayed after iv contrast injection). There is a pelvic fluid collection (arrows) with enhancing wall and located next to sigmoid colon, compatible with abscess.

**References**: Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES

Adhesions can also be found secondary to transmural ulcers, and they can be either inflammatory active or fibrotic (Figures 8 and 15).
Fig. 15: Figure 15. Fibrotic adhesions. A. Coronal FIESTA. There is a thin tract (arrow) from right colon to the surrounding intraabdominal fat. Note the tent-like effect on colon wall. B. Coronal baseline 3D GRE T1WI fatsat. Thin tract from right colon to surrounding fatty tissue (arrow) C. Coronal 3D GRE T1WI fatsat (delayed after iv contrast injection), there is faint enhancement of the tract (arrow), thus meaning that the it is probably a fibrotic adhesion.

References: Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES

-Fibro-stenotic disease.

It is a long-term evolution subtype of CD in which intestine loops have suffered from chronic inflammation and develop fibrosis.

Imaging findings of intestinal fibrosis

- Bowel wall thickening without acute inflammatory changes
- Hypointensity of signal of the bowel wall in T2WI fat suppressed
- Faint and inhomogenous wall enhancement
- Pseudosacculations

Low-to-moderate wall signal in T2WI and absence of inflammatory findings in a bowel loop showing a thickened wall favours the diagnosis of fibrosis [11] (Figure 16).
Fig. 16: Figure 16. Fibrotic changes in bowel loops. A. Coronal SSFSE T2WI. There are several small bowel loops in RUQ that show wall thickening with low signal intensity (arrows). B. Coronal SSFSE T2WI fatsat. The mentioned bowel loops do not have increased signal after fat saturation, meaning that there is no significant oedema (arrows). C. Coronal 3D GRE T1WI fatsat (delayed after iv contrast injection). The small bowel loops have full-thickness faint enhancement (arrows). These findings are compatible with bowel wall fibrosis.

References: Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES

Faint and specially non-stratified and inhomogeneous wall enhancement in a thickened wall bowel loop is related to fibrosis [10] (Figure 16).

Abnormal pseudosacculation of intestinal loops indicates chronic damage and fibrosis of the loop (Figure 17).
**Fig. 17:** Figure 17. Pseudosacculation of a bowel loop. Detail from a coronal SSFSE T2WI. There are several small bowel loops with thickened wall but in LLQ there is a change of caliper with a pseudo-dilated intestine segment which has lost its normal anatomic appearance. This is called pseudosacculation and it is a typical finding of the fibrotic-stenotic subtype of CD.

**References:** Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES

**Reparative-regenerative disease.**

It is distinguished by mucosal atrophy, regenerative polyps (not to be confused with inflammatory pseudopolyps) and absence of active inflammation.

Several MR-E findings have been related to long-term evolution of CD
Abnormal bowel loop morphology

Fatty infiltration of submucosa

Fatty infiltration of the submucosa is a characteristic sign of chronic CD [14] (Figure 18).

**Fig. 18**: Figure 18. Fatty infiltration of submucosa. A. Detail from axial SSFSE T2WI. There are high signal intensity areas within bowel wall (arrows). These areas lose their signal (arrow) in B. SSFSE T2WI fatsat. This is compatible with fatty infiltration of the submucosa, a typical finding of chronic CD. C. Detail from axial SSFSE T2WI and D.
axial SSFSE T2WI fatsat from a different patient. It can be also observed that high signal intensity areas in C. show a loss of signal when fatsat is performed in D. It is compatible with fatty infiltration of the submucosa layer. 

**References:** Radiodiagnostico, Servicio Madrileño de Salud, Hospital Clinico San Carlos - Madrid/ES

Mesenteric fat hypertrophy is a typical finding in CD [10, 18] (Figures 3 and 8).
Conclusion

The role of MR-E in the management of CD is rapidly increasing in importance, because it determines therapeutic decisions which affect the patient's outcome. Thus it is important for radiologists to be familiar with its imaging findings.


