The essential of inflammatory bowel disease- from ultrasound to MRI in pediatric imaging

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Learning objectives

To list and illustrate imaging features of inflammatory bowel diseases (IBD) in the pediatric population and the role of ultrasound (US), CT-scan and MRI in diagnosis and follow-up.
Background

Definition

• IBD is one of the most common intestinal disease affecting pediatric patients and young adults in the developed world, that has incapacitating and long duration symptoms and needs high resources for the diagnosis and treatment.

Classification

• Crohn disease (CD) and ulcerative colitis (UC) are the two predominant subtypes of IBD, with different distribution of gastrointestinal tract involvement and gravity of the inflammatory degree.

• CD has a high incidence in the adolescent population, with potential involvement of the entire gastrointestinal tract; therefore, CD can leads to lifelong intermittent symptomatic recurrence and medical rather than surgical management is the primary therapy [1].

• The bowel disease in UC, less spread among adolescents, is confined to the colon, with surgical solutions in patients without response to medical treatment, but they tend to have more severe and extensive disease at presentation, 90% having total colonic involvement at presentation [1].

• Neutropenic enterocolitis, also known as typhlitis (from Greek typhlon ["blind"], referring to the cecum), is an acute life-threatening condition characterized by transmural inflammation of the cecum, often with involvement of the ascending colon and ileum, in patients who are severely myelosuppressed [2].

Forms of IBD:

# Non complicated IBD

# Complicated IBD

  » Acute/subacute/chronic

Incidence
IBD is most common in North America and western and northern Europe, where incidence rates for UC and CD range from 2.2-24.3 per 100000 person years [3].

There is no major gender predominance in IBD, with peak age of onset between 15-30 years of age, but it is estimated that up to 20% of people with IBD are diagnosed during childhood and the incidence and prevalence of pediatric IBD are increasing worldwide [3].

Clinical signs

Symptoms of IBD are variable in time, with periods of "flare" and "remission".

**UC and CD** share some clinical and physiologic features and are distinct in others. The main difference is that while the chronic inflammation seen in UC is limited to the colon and rectum and affects only the intestinal mucosa, the inflammation in CD can occur at any location(s) along the gastro-intestinal tract and is often transmural, predisposing patients with CD to the development of penetrating (fistulizing) and fibrostenotic (stricturing) lesions [3].

Clinical manifestations of **UC** include diarrhea, with or without blood, abdominal pain, tenesmus, and fecal urgency while the manifestations of CD are more variable depending on the extent and location of the GI inflammation [3].

**CD** with predominantly colonic involvement is similar to UC whereas in small bowel CD, diarrhea and rectal bleeding are seen less frequently and fever, fatigue and weight loss are common [3].

Extraintestinal manifestations, such as arthritis, primary sclerosing cholangitis, skin and ocular involvement, occur in more than 1/3 of IBD patients [3].

Linear growth attenuation and pubertal delay are common among children with IBD: up to 30% of children with CD have linear growth failure [3].

The clinical presentation of **neutropenic enterocolitis** can be dramatic and may include diarrhea, abdominal distension and pain, fever, nausea, vomiting and the outcome may be devastating [2].

Positive diagnosis
The diagnosis of IBD is most commonly made on the basis of clinical features in combination with findings on endoscopy and histopathology [3].

**Imaging options**

Although the final diagnostic needs endoscopy and histopathology, imaging is necessary at all stages of the disease, given the relapsing remitting nature of the disease.

Imaging options: **ultrasound** and cross-sectional imaging tools: CT and MRI with dedicated techniques like **CT/MR enterography/enteroclysis** [1]. Enteroclysis involves insertion of a naso-jejunal catheter and infusion of contrast material through the catheter, being quite invasive and suboptimal for pediatric patients [1].

- Current roles of imaging in IBD patients includes:
  1. at the time of initial diagnosis to assess intestinal and extraintestinal manifestations of IBD and if possible to distinguish UC from CD;
  2. to visualize penetrating complications of disease that extend outside the bowel wall;
  3. to assess disease activity in patients with known IBD during symptomatic recurrence [3].

**US**

US advantages are:

- available, non-invasive, non-irradiating
- repetitive, without sedation, or bowel preparation
- useful for diagnosis or monitoring, detects wall thickening, with good layers evaluation
- sensitive, but non-specific for IBD
- can show peri-intestinal inflammatory changes.

US disadvantages are:

- operator dependent
- cannot detect stenosis
- not-reliable for real extent.

**CT enterography**

Advantages:

- relatively accessible, repetitive
• needs bowel preparation invasive (limited for small children) or non-invasive
• detect wall thickening if major, with layers differentiation if intravenous contrast administration
• detect stenosis
• full and reliable extension of the bowel lesions
• very good in peri-intestinal changes or for complications.

Disadvantages:

• radiation exposure, prohibitive in children, therefore used only for complications, not in follow-ups
• less sensitive than US for intestinal wall layers differentiation.

**MR enterography**

**Advantages:**

• no radiation exposure and repetitive
• can be used for periodic evaluations or follow-ups
• needs bowel preparation, invasive or non-invasive
• detect wall thickening, stenosis
• full and reliable extension of the bowel lesions depending on technique and patient
• can evaluate intestinal peristalsis on dynamic studies
• can detect active stages on DWI sequences.

Disadvantages:

• long-duration
• might needs sedation
• relatively inaccessible, cannot be used for complications
• limited for peri-intestinal changes
• less sensitive than US for intestinal wall layers differentiation.

**Role of imaging**

To assess the presence of: classical signs, location and extension of intestinal lesions, the degree of wall thickening, the extraluminal manifestations, complications, or others incidental lesions.

**Differential diagnosis**

Other diseases with symptoms mimicking IBD:

• celiac disease,
• Meckel diverticulum,
• infectious colitis,
• pseudomembranous colitis,
• ischemic colitis,
• intestinal tuberculosis,
• radiation-induced colitis,
• neuroendocrine tumor [1].
Findings and procedure details

Our study includes patients with Crohn disease (CD), ulcerative colitis (UC) or neutropenic enterocolitis (NE), presented for diagnostic, monitoring or during a relapse, with complications, explored by US, CT or MRI and particularly CT/MR-enterography techniques.

Imaging attributes to consider:

- Sensitivity
- Specificity
- Availability
- Invasivity
- Tolerance
- Irradiation

Technique

1. US technique

- No ionising radiations used

- No bowel preparation needed

- Both convexe or linear probe used

- High frequency linear probe is mandatory in children for bowel wall imaging, it can depict normal bowel wall stratification in order to detect any thickening (Fig. 1 on page 22).
Fig. 1: F, 14 y, CD remission phase, US: normal stratification of the intestinal wall, with hyperechoic submucosal layer (arrow).

References: Radiology and Medical Imaging Department, Fundeni Clinical Institute, Bucharest, Romania

- Doppler mode is useful in inflammatory changes of the intestinal wall: increasing of vascular number and caliber.

- Can detect extra-luminal modifications: ascites, peritoneal sheet thickening, hyperechoic and inflammatory thickening of the peritoneal fat.

- Depending of technique or radiologist experience can detect some complications: abscess, perforation.

2. CT/MRI enterography/colonography

- Entails reliable and controlled distention of the small bowel and allows assessment of bowel distensibility and stricture.
• We used negative contrast (diluted manitol) for intestinal distension in order to visualize
the intestinal wall morphology or to evaluate the bowel caliber (stenosis or abnormal
distension).

• Positive oral contrast (diluted iodine for CT scans) is necessary in patients with acute
symptomatology if complication like abscess or collection is suspected.

• Antiperistaltic medications can be administered intravenously in order to reduce
peristalsis and motion artifacts (especially in MRI).

• Enterography technique consists in specific acquisition at 30-45 minutes after contrast
oral ingestion, in order to explore de small bowel.

• Colonography technique needs previous colonic evacuation followed by oral negative
contrast administration and specific late acquisitions.

• Enema administration on CT/MRI table is difficult in pediatric population and can be
harmful during inflammatory acute stages.

CT technique considerations:

• Because of the major ionizing radiation exposure in CT and high pediatric
population sensitivity to radiation, one needs to limit the number of
acquisitions and use special pediatric CT protocols
• No sedation generally needed
• We reduced the exam to one acquisition after intravenous iodine injection in
venous phase in order to reduce the ionizing radiation.

MR technique considerations:

• MR enterography has long-duration, we used sedation for children under
age of 5-6 years
• Our MRI exam includes: HASTE and true FISP morphological sequences
in axial, coronal or oblique plane; axial DWI b=800 (for active stages of the
disease), CINE sequences (for peristaltic studies)
• Dynamic multiphasic 3D T1 FatSat acquisitions in axial or coronal plane can
be used after Gd contrast intravenous injection in order to characterize the
intestinal wall enhancement.

Imaging findings
1. US

- Ultrasound detects in children the inflammatory stratified (Fig. 2 on page 22) or nonstratified bowel thickening (Fig. 3 on page 23).

![Image of ultrasound scan](image)

**Fig. 2:** F, 15y, CD; US, linear probe; submucosal thickening affecting descending and sigmoid colon (arrow); note the wall's layers differentiation preserved.

**References:** Radiology and Medical Imaging, Fundeni Clinical Institute, Bucharest, Romania
Fig. 3: F, 2y, post chemotherapy NE; US, linear probe, axial plane; marked non-differentiated thickening of the rectal wall (little star); inflammatory aspect of the perirectal fat: hyperechoic thickening (big star).

References: Radiology and Medical Imaging Department, Fundeni Clinical Institute, Bucharest, Romania

- In Doppler mode, congestive inflammatory aspect of the bowel's wall and adjacent peritoneal fat can be revealed even with high frequency linear probe by increasing in number and caliber of the vessels (Fig. 4 on page 24).
Fig. 4: M, 15y, UC active phase; US, linear probe, Doppler mode; A: inflammatory vascular congestion of the peritoneal fat and descending colon wall (thick arrow) with hyperechoic thickening of his submucosal layer (thin arrow); B: small adenopathies (thick arrow) and peritoneal hyperechoic fat thickening (thin arrow).

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- Other inflammatory signs like lymphadenopathies, ascites or peritoneal thickening can be diagnosed during US (Fig. 5 on page 25).

Fig. 5: F, 2y, post chemotherapy NE; US, linear probe, axial plane: peritoneal sheet thickening (black arrow) and mild ascites (white arrow).

References: Radiology and Medical Imaging Department, Fundeni Clinical Institute, Bucharest, Romania

- In case of BID complication, experienced user can image by US abscess or abnormal abdomino-pelvic collection (Fig. 6 on page 25). This can be
challenging in adolescents with large muscular mass and more easy task in small children.

**Fig. 6**: M, 17y, complicated CD, acute inflammatory symptoms, US, plane and convex probe; A: poorly stratified ascending colon thickening (thin arrow); B: peri/hepatic abscess (thick arrow); C, D: pelvic supravezical multiloculated collection with septa (white star); yellow star- urinary bladder.

*References*: Radiology and Medical Imaging, Fundeni Clinical Institute, Bucharest, Romania

2. CT scan/enterography

- CT is useful in acute stages for evaluating more precisely complications (abscesses), for depicting parietal intestinal thickening and peritoneal
inflammatory changes, but with less sensibility then ultrasound for detecting the stratification of the intestinal wall (Fig. 7 on page 26).

Fig. 7: M, 17y, complicated CD, acute inflammatory symptoms, CECT, venous phase, positive oral contrast; A: peri/hepatic multiloculated abscess (thick arrow); B, C (coronal MPR reconstruction): major cecal and ascending colon parietal thickening with no differentiation between layers (thin arrow), good depicting of peritoneal inflammatory changes- fat densification, vascular congestion, fluid, small lymphadenopathies (angulated arrow); very good displaying of the pelvic collection (white star) and the fistulous tract towards the cecum (little white star); yellow star- urinary bladder.

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- CT-enterography techniques in active or chronic stages reveal the extent and degree of bowel thickening and stenosis, but with the disadvantage of radiation, significant in the pediatric population (Fig. 8 on page 27).
- "Comb sign" refers to the hypervascular appearance of the mesentery in active IBD, with fibrofatty proliferation and perivascular inflammatory infiltration outline the distended intestinal arcades [4].
**Fig. 8:** A, B: 18y, CD, CECT, venous phase, negative oral contrast: terminal bowel thickening (thin arrow), no stratification of the wall visible and focal mild stenosis (white star); mild "comb sign" (thick arrow); lymphadenopathies (inside white circle). C, D: 17y, CD, chronic evolution, relapsing phase; CECT, venous phase, positive oral contrast: rectal and sigmoid parietal thickening (thin arrow) without layers stratification visible and long stenosis of the sigmoid (white star); major "comb sign"(thick arrow).

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3. **MR enterography**

- MR-enterography in a multiparametric and noninvasive approach is useful for: the detection of the thickened intestinal segment with T2 weighted sequences and in the same time appreciation of active inflammatory stage of the disease, grace to the diffusion sequence and ADC map (**Fig. 9** on page 28). This criteria is very useful in managing therapeutic decision, or monitoring therapeutic response during treatement.
Fig. 9: M, 17y, CD, relapsing phase; MR- enterography with negative oral contrast; A, B: cecal and ascending colon parietal thickening with no differentiation between layers visible on coronal T2 fat sat weighted acquisition (thin arrow), with major peritoneal inflammatory changes (thick arrow). C, D: restricted area in parietal ascending colon, with hyperintensity on DWI (b=800) and hypointensity on ADC map, signifying active stage of the disease.

References: Radiology and Medical Imaging Department, Fundeni Clinical Institute, Bucharest, Romania

- With the help of multiplanar T2 weighted HASTE and true FISP acquisitions, we can obtain, without disadvantage of ionizing radiation of the CT-scan, the precise extension of the stenosis (Fig. 10 on page 29).
Fig. 10: F, 18 y, CD, MR-enterography, with negative oral contrast, T2 weighted axial (A), coronal (B) and sagittal (C) true FISP acquisitions: terminal ileal loop thickening without stratification visible, in association with long stenosis (thin arrow); lymphadenopathies and peritoneal mesenteric inflammatory changes (thick arrow).

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- During CINE sequences consisting of T2 weighted true FISP acquisitions placed on the specific modified intestinal segment (if stenosis of the small bowel and ileo-cecal junction), one can establish the lack of normal movements if fibrosis is installed in chronic stages (video- Fig. 11 on page 30).
**Fig. 11:** F, 18 y, CD, MR- enterography, with negative oral contrast, T2 weighted sagittal true FISP multiple slide acquisitions (CINE sequence): terminal ileum loop thickening without and long stenosis without peristalsis movements.

**References:** Radiology and Medical Imaging Department, Fundeni Clinical Institute, Bucharest, Romania

**Differential diagnosis** in imaging between UC and CD is difficult, can be made on the basis on different location and depth of the inflammation of the diseases: **CD** lesions tend to perforate the parietal wall with ulceration and abscess formation and are multifocal, while **UC** is limited to the parietal wall and affects only the large intestine.

- Peritoneal changes like lymphadenopathies, fat inflammation and vascular congestion are non-specific in active phases.
The essential in comparative results

- **Ultrasound** can detect in children the nonspecific inflammatory stratified bowel thickening and sometimes the complications, being most useful because his accessibility and lack of radiation.

- **CT-scan** is very useful for evaluating the real extent of IBD, complications in active or chronic stages by using entero-CT techniques; it reveals ulcerations, abscesses, bowel stenosis, but with the disadvantage of radiation, major in pediatric population.

- **Entero-MRI** technique is newer and less accessible, being an useful alternative to CT-scan without X-rays, especially for appreciation of active stages of the disease, ileum peristalsis and extension of the stenosis. It can also reveal inflammatory bowel findings like wall thickening (but less sensitive than US concerning the wall stratification) or peritoneal changes.

<table>
<thead>
<tr>
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<tr>
<td></td>
<td>- - extension</td>
<td>- - stratification</td>
<td>- - stratification, movements artifacts</td>
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<tr>
<td>Specificity</td>
<td>NO</td>
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**Fig. 12**: Table 1: Comparative results

**References**: Radiology and Medical Imaging Department, Fundeni Clinical Institute, Bucharest, Romania

**IMAGING ALGORITHMS IN PEDIATRIC IBD** *Fig. 13 on page 31*
**Fig. 13**: Table 2: Role of imaging in diagnosis and monitoring IBD

**References**: Radiology and Medical Imaging, Fundeni Clinical Institute, Bucharest, Romania
**Fig. 1:** F, 14 y, CD remission phase, US: normal stratification of the intestinal wall, with hyperechoic submucosal layer (arrow).

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- **US**
  - Used at the onset and for monitoring relapses
  - Reliable for measure and follow-up submucosal thickness

- **CT**
  - Used only for acute complications (abscesses, collections)
  - Good for peri-intestinal changes

- **MRI**
  - Used at the onset and monitoring relapses
  - Complete extent of the parietal thickness or stenosis
  - Detect active phases of the disease

**Fig. 13:** Table 2: Role of imaging in diagnosis and monitoring IBD

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Conclusion

In children with IBD, ultrasound is indicated for diagnostic and monitoring, while CT/MRI-enterography are used for complication detection and evaluation of complete extension of the lesions.
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