PICTORIAL ESSAY | Gastrointestinal Imaging

The spectrum of imaging features regarding Crohn's Disease Complications with CT and MR Enterography. A Pictorial Essay

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ABSTRACT

Crohn's disease is a chronic inflammatory disorder of the gastrointestinal tract that presents significant diagnostic challenges due to its varied manifestations and potential complications. Accurate and timely imaging is essential for assessing disease activity and managing mural and extra-intestinal abnormalities effectively. CT and MR enterography are crucial in diagnosing and evaluating the complications of Crohn's disease, providing detailed insights into disease extent while offering comprehensive anatomical and functional information non-invasively. This pictorial essay illustrates the spectrum of imaging features associated with Crohn's disease complications, from segmental mural hyperenhancement and strictures to penetrating manifestations such as fistulas and abscesses. Additional focus is given in identifying Crohn's-related appendicitis, post-surgical recurrence, and the rare development of carcinoma. By understanding the distinctive imaging features and procedural nuances of CT and MR enterography, radiologists can better tailor therapeutic strategies, ultimately improving patient outcomes.

KEY WORDS: Computed Tomography Enterography, Magnetic Resonance Enterography, Crohn disease.

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Introduction

Crohn's disease (CD) is a chronic inflammatory bowel disease characterized by a relapsing, remitting inflammation that can affect any part of the gastrointestinal tract, most commonly the terminal ileum and colon. CD often presents with a wide range of clinical manifestations, including abdominal pain, diarrhea, weight loss, and fatigue, due to its involvement in both the bowel wall and the surrounding mesentery [1]. Pathophysiologically, CD is marked by the interaction of genetic, environmental, and immune factors that trigger transmural inflammation. This inflammation can progress over time, leading to bowel damage in the form of strictures, fistulas, and penetrating complications, which significantly affect the patient's quality of life and may require surgical intervention [2].

Imaging plays a central role in diagnosing, staging, and monitoring CD, providing essential information beyond what clinical assessment and endoscopy can offer. Cross-sectional imaging methods, particularly CT enterography (CTE) and MR enterography (MRE), have become indispensable in evaluating disease extent, activity, and associated complications. Both modalities are highly effective in capturing bowel wall thickening, mural hyperenhancement, and mesenteric involvement—key indicators of active inflammation. Furthermore, MRE offers the advantage of avoiding ionizing radiation, making it preferable for younger patients and those requiring repeated scans. Meanwhile, CTE, with its faster acquisition times and superior spatial resolution, is often advantageous in emergency settings or when patient compliance is a challenge [3].

This essay aims to illustrate the imaging characteristics of CD across various stages and complications, underscoring the importance of CTE and MRE in detecting both intramural and extramural disease manifestations. By showcasing a comprehensive set of radiological features, the essay highlights the value of imaging in optimizing disease management, predicting complications, and ultimately improving patient prognosis.

Technique

Our enterography protocol involves an 8-hour fasting period prior to the procedure. This helps minimize food residue and debris in the intestinal lumen, reducing the risk of mistaking them for polyps or mass lesions [1]. Additionally, unless contraindicated, patients are advised to follow a liquid diet for three days beforehand [4]. This low-residue approach decreases fecal content in the colon, facilitating the transit of the small-bowel contrast agent by preventing delays caused by residual material in the bowel [1].

Our protocol includes the oral ingestion of 1250 mL of a 20% mannitol solution, consumed over 35 minutes at a rate of 250 mL every 7 minutes [4]. This hyperosmolar preparation draws fluid into the bowel, promoting effective bowel distension, which enhances visualization. Proper bowel distension allows for improved assessment and delivers biphasic MRI soft tissue contrast, appearing as low signal intensity on T1-weighted images and high signal intensity on T2-weighted images.

Before scanning, patients are instructed to empty their bladder to enhance comfort during the procedure [1].

When not contraindicated, an antispasmodic agent was administered intravenously before the examination. This practice helps reduce intestinal peristalsis and mucosal folding, minimizing motion artifacts and improving image clarity [1].

CTE scanning was performed on an 80 slice multi-detector scanner 45 seconds post- injection of a non-ionic iodinated contrast media (350-370mgI/ml) with a rate of 4ml/s in order to image the bowel (enteric phase). The total volume of non-ionic contrast media administered was based on body weight at a dosage of 1 ml/kg, typically ranging from 60 ml to 120 ml. Post-processing was conducted on a workstation, utilizing axial plane imaging with a slice thickness of 1-2 mm, along with multi-planar reformation (MPR) and maximum intensity projection (MIP) techniques.

Dynamic MRE studies were performed using a 3T scanner post injection of 15 mL of gadolinium contrast media, in order to image the bowel. A thorough MRE examination of the small bowel typically includes both axial and coronal T1- and T2-weighted sequences. These often incorporate T2-weighted imaging with fat suppression, such as HASTE sequences, to enhance visualization of bowel wall abnormalities. Additionally, fat-suppressed three-dimensional (3D) T1-weighted breath-hold gradient-echo sequences are obtained for the abdomen and pelvis, performed both before and after the administration of gadolinium-based intravenous contrast material to evaluate inflammatory activity, vascularity, and other pathological changes.

CTE vs MRE

The primary advantage of magnetic resonance imaging (MRI) over computed tomography (CT) is its lack of ionizing radiation, making MRE particularly suitable for children and young adults who require frequent imaging due to the chronicity of certain pathologies. MRE offers dynamic assessment capabilities through real-time imaging sequences, allowing for the evaluation of peristalsis and mural enhancement patterns, which help distinguish between different wall compositions, including fibrostenotic disease. It excels in visualizing extraluminal complications of CD, a benefit it shares with CTE.

On the other hand, CT is more appropriate for uncooperative patients, as it requires fewer breath holds, enhancing patient compliance. It is also preferred in emergency situations due to its rapid and accurate depiction of perforations and its ability to identify extraintestinal lesions that may contribute to acute abdominal conditions. CTE has advantages over MRE in terms of shorter imaging duration and higher spatial resolution; it allows for multiplanar reformation with high resolution images and can assist in interventional procedures, such as percutaneous drainage of intra-abdominal abscesses. The acquisition time for CTE is significantly shorter, typically 8-10 seconds, compared to 20-30 minutes for MRE.

Both CTE and MRE face limitations in accurately identifying fibrotic lesions. While CTE findings related to bowel wall inflammation correlate well with tissue inflammation, there is no strong correlation between imaging findings suggesting fibrosis and the actual presence of histological fibrosis. Histological inflammation and fibrosis are closely related and do not appear to be distinct entities.

Therefore, CTE and MRE likely struggle to reliably assess fibrosis, whether or not accompanied by inflammation, since these conditions do not function as mutually exclusive stricture types [3].

Findings

- **Bowel Wall Imaging Findings Associated with Crohn Disease Inflammation**

  CTE and MRE serve as valuable tools for detecting the presence of disease, evaluating its activity and severity, determining its extent, and assessing potential complications. The most distinctive indicator of active CD is mural hyperenhancement accompanied by wall thickening, which can manifest asymmetrically, in layers, or uniformly [3].

- **Segmental Mural Hyperenhancement**

  Asymmetrical mural hyperenhancement, primarily affecting the mesenteric border, is a key feature seen in active CD. Layered mural enhancement creates a "target" appearance due to increased enhancement in the inner and/or outer layers of the bowel wall along with submucosal edema [5,4] **(Fig.1)**.

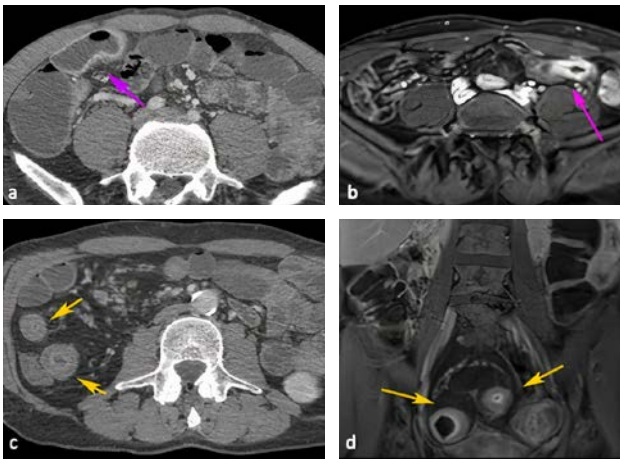

Fig.1: *Axial contrast-enhanced CTE image (a) and axial contrast-enhanced fat-suppressed T1-weighted MRE image (b) show asymmetrical mural hyperenhancement (purple arrows). Axial contrast-enhanced CTE image (c) and axial contrast-enhanced fat-suppressed T1-weighted MRE image (d) show stratified pattern of enhancement of the inner aspect of the wall creating a "target" appearance (yellow arrows).*

Uniform mural hyperenhancement, depicted by a two-layered appearance, lacks specificity for active CD and can occur in various bowel conditions such as fibrosis, ischemia, and shock bowel. Other indicators of active CD include prominent vasa recta (resembling a "comb sign"), inflammation-induced mesenteric fat stranding, and enlarged mesenteric lymph nodes.

The chronic phase of CD is marked by inflammation resolution with residual changes evident in imaging, such as submucosal fat deposition, antimesenteric border outpouchings, fibrofatty proliferation, mild mural enhancement, and fibrotic strictures. The "fat halo sign" indicates past or chronic inflammation, characterized by a three-layered appearance with intramural fat.

Additionally, mild mural enhancement resembling

muscle density can predict, albeit nonspecifically, chronic conditions like CD, ischemia, or radiation damage [5,4] **(Fig.2)**.

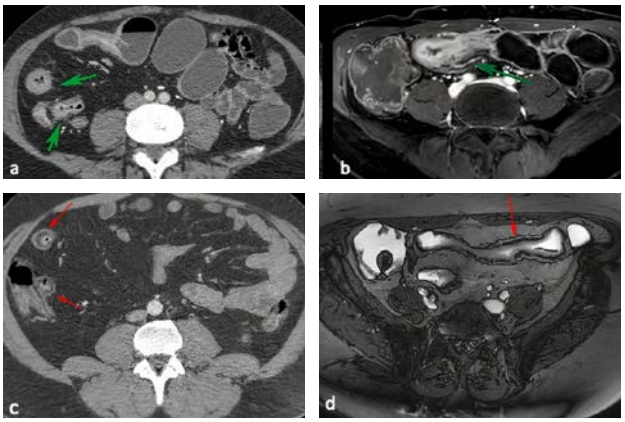

Fig.2: *Axial contrast-enhanced CTE image (a) and axial contrast-enhanced fat-suppressed T1-weighted MRE image (b) show homogeneous symmetrical mural hyperenhancement (green arrows). Axial contrast-enhanced CTE image (a) and axial contrast-enhanced fat-suppressed T1-weighted MRE image (b) show "fat halo sign" (red arrows).*

- **Strictures**

  Fibrostenotic disease, which occurs in approximately 18-27% of CD patients within 10-20 years post-diagnosis, is characterized by bowel wall thickening and luminal narrowing that may lead to proximal dilation, often defined as ≥3 cm [3].

  Strictures are identified by a reduction in bowel diameter of at least 50% compared to adjacent, unaffected loops, and they can present with or without active inflammation. However, most strictures exhibit some degree of active inflammation, which can guide treatment options. Strictures without active inflammation may display reduced T2-weighted MR signal intensity and sometimes fecalized content in the proximal bowel, signaling stasis and potential bacterial overgrowth [6].

  Stricture development is often linked with penetrating disease, such as fistulas or inflammatory masses; hence, if penetrating complications are present, adjacent bowel segments should be evaluated for strictures, as they are typically inflamed. Conversely, an active inflammatory stricture should prompt assessment for associated penetrating disease, like fistulas, which commonly arise in the mid or proximal areas of the stricture [2]. Surgical resection for intestinal obstruction due to fibrostenotic strictures is common in CD, especially in the ileum and ileocolonic regions, where the smaller diameter predisposes these areas to strictures.

  Studies reveal that around 25% of CD patients have small bowel strictures, while 10% have colonic strictures. Post-surgical recurrence, particularly at the anastomosis site, is a frequent complication [6].

  Radiological imaging is crucial for stricture detection and evaluation. CTE and MRE show similar sensitivity and specificity in identifying stenosis, with CTE reaching sensitivities of 85-90% and MRE showing 89% sensitivity and 94% specificity when compared to endoscopic and surgical standards [3].

  Histologically, strictured segments often demonstrate smooth muscle hypertrophy alongside fibrosis and inflammatory cell infiltration.

  The length and location of strictures, their association with anastomotic sites, and any concurrent inflammation or proximal dilation should be documented, as these factors influence management, including potential responses to endoscopic therapy for anastomotic versus native small bowel strictures [2].

  - **Probable Stricture Without Upstream Dilation (<3 cm)**

    Several situations can lead to a stricture without noticeable upstream dilation (<3 cm) **(Fig.3)**.

    One example is when a fistula or other penetrating complication forms near a stricture with

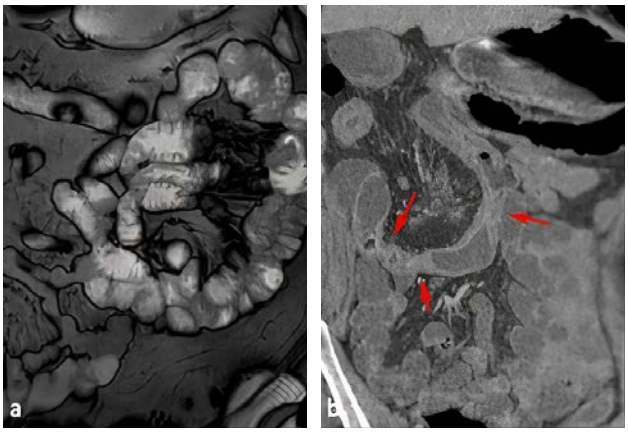

Fig.3: *Coronal fat-suppressed T2-weighted MRE image (a) shows probable stricture without upstream dilatation. Coronal contrast enhanced CTE image (b) shows multiple strictures (red arrows) close together without upstream dilation.*

active inflammation, which can decompress the upstream bowel segment, preventing dilation. Another scenario is when there are multiple nearby strictures; here, the more distal stricture may not cause upstream dilation because the proximal stricture already impedes bowel flow. Lastly, if imaging consistently shows fixed luminal narrowing without upstream dilation across multiple MR pulse sequences or follow-up exams, the impression might indicate a "probable stricture without upstream dilation" [5].

- **Stricture with Mild Upstream Dilation (3–4 cm)**
  When a stricture is present, there is often mild dilation (3–4 cm) of the upstream bowel segment. Additionally, the proximal small bowel may show small bowel debris or fecalization, known as the "small bowel feces sign," which suggests a long-standing narrowing [5] **(Fig.4)**.

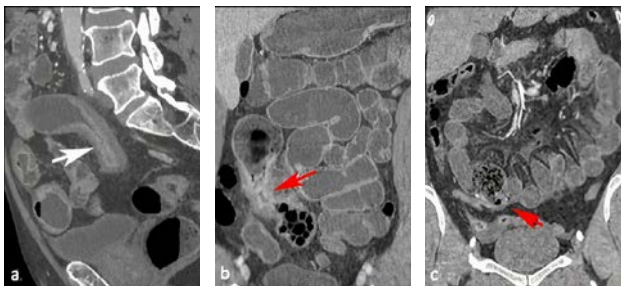

Fig.4: *Sagittal (a) and coronal (b, c) contrast enhanced CTE images show mural thickening resulting in stenosis (arrows on a and b) with moderate overlying bowel dilation, along with the small bowel "feces sign" in the proximal part of the small bowel (arrow on c).*

- **Stricture with Moderate to Severe Upstream Dilation (>4 cm)**
  The presence of moderate to severe upstream dilation greater than 4 cm, along with a stricture, may suggest a small bowel obstruction **(Fig.5)**. Surgical removal of the affected segment of the intestine may be necessary [5].

- **Ulcerations**
  An ulceration refers to a disruption in the inner surface of the bowel wall, allowing intraluminal contents, such as contrast material, to penetrate into the bowel wall. It is important to avoid the term "penetrating ulcer" to prevent confusion with conditions that involve penetration, such as sinus tracts, fistulas, or abscesses. By definition, an ulcer is a defect that is limited to the bowel wall, unlike a sinus tract, which is a defect that extends through the serosa into the mesenteric fat [5] **(Fig.6)**.

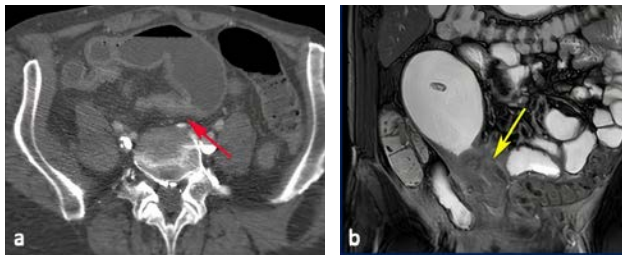

Fig.5: *Axial contrast enhanced CTE image (a) show mural thickening (red arrow) resulting in stenosis with high grade overlying bowel dilation. Coronal fat-suppressed T2-weighted MRE image (b) show mural thickening (yellow arrow) resulting in stenosis with high grade overlying bowel dilation.*

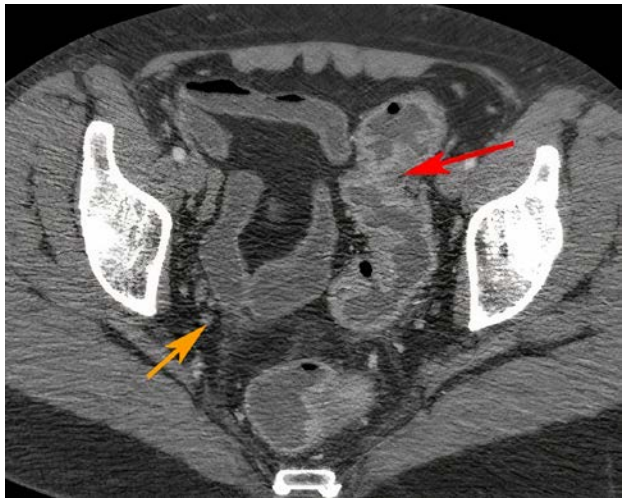

Fig.6: *Axial contrast enhanced CTE image show multiple intramural ulcers of the colon (red arrow) with segmental fibrostenotic disease of small bowel (orange arrow).*

- **Sacculations**
  Sacculations, also known as pseudosacculations, are broad-based protrusions along the antimesenteric border of a bowel loop. These formations arise from asymmetric shortening along the mesenteric border due to either acute or chronic bowel wall inflammation and fibrosis, resulting from ulceration on the mesenteric side **(Fig.7)**. Sacculations may indicate the presence of acute or long-standing disease processes, including fibrosis [5].

■ **Imaging Findings of Penetrating Crohn's Disease**

This subtype of the disease is marked by intense inflammation that leads to transmural ulceration and the formation of fistulas. Penetrating complications arise due to transmural inflammation and may involve the formation of sinus tracts, fistulas, inflammatory masses, abscesses, and, in rare cases, free intraperitoneal perforation. When dealing with penetrating disease, visual examination should focus on identifying the origin of the fistula, typically marked by an inflamed and narrowed bowel segment with upstream dilation, as these features are almost always present. Similarly, the proximal end of an inflamed and stenotic bowel segment should be carefully examined to detect penetrating complications, as they most often originate from this area of the affected segment [7].

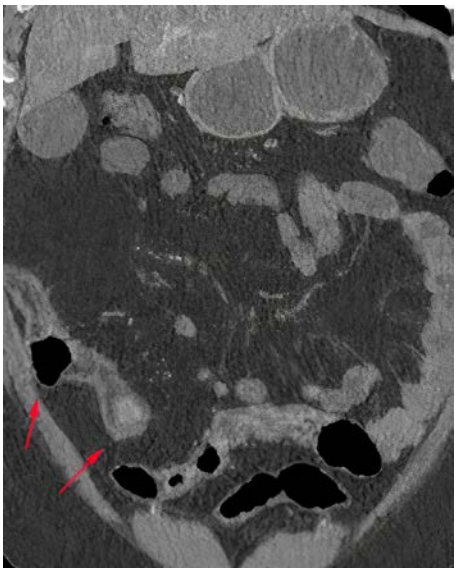

Fig.7: *Coronal contrast enhanced CTE image shows several sacculations along the antimesenteric wall (red arrows) of a small bowel segment.*

- **Sinus tract**

  A sinus tract is defined as a blind-ending channel that extends beyond the serosal layer of the bowel wall without reaching adjacent organs or the skin [5] **(Fig.8)**.

- **Fistulas**

  A fistula is defined as a tract that connects the bowel lumen to another epithelialized surface, which may or may not contain fluid. Simple fistulas typically arise from the mid or proximal aspect of a stricture, often occurring in conjunction with active inflammation.

  Fistulas commonly originate from the serosal surface of inflamed bowel loops, linking the diseased bowel to adjacent organs, other bowel segments, or the skin.[5] They are categorized based on the structures they connect, including enteroenteric, enterocolic, enterovesical, enterocutaneous, and rectovaginal types [6].

  On imaging studies, simple fistulas appear as hyperenhancing tracts on CTE and linear regions of increased signal on T2-weighted MRE [5] **(Fig.9)**.

  A complex fistula is characterized by the existence of multiple fistulous tracts. Desmoplastic and fibrotic reaction in the mesentery around an inflamed fistula can leading to a small bowel con-

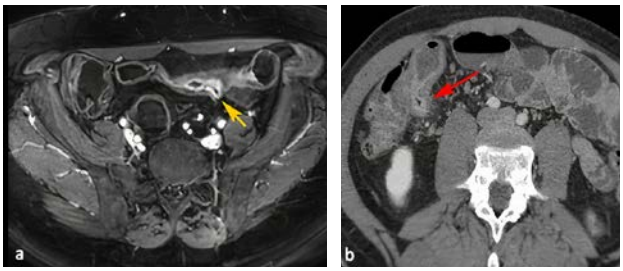

Fig.8: *Axial contrast-enhanced fat-suppressed T1-weighted MRE image (a) and contrast-enhanced CTE image (b) show mural thickening and a blind-ending sinus tract (arrows) arising from the ileum.*

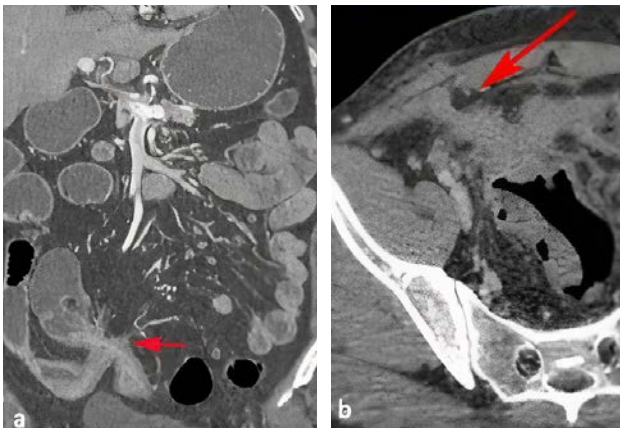

Fig.9: *Coronal (a) and axial (b) contrast enhanced CTE images show small bowel wall thickening and bowel wall edema, findings consistent with active inflammatory Crohn disease with an associated enteroenteric (a) and an enterocutaneous fistula (b) (red arrows).*

figuration resembling an asterisk (referred as the "star sign") or cloverleaf due to the bending and anchoring of the involved bowel segments.
Additionally, there may be other penetrating complications like an inflammatory mass or interloop abscess that can also occur [5] **(Fig.10)**.

Fig.10: *Coronal contrast-enhanced CTE image (a) and contrast-enhanced fat-suppressed T1-weighted MRE image (b) show mural thickening with hyperenhancement and multiple associated enteroenteric fistulas extending into the adjacent mesentery with tethering, leading to multiple small bowel loops with an asterisk appearance (arrows).*

CTE and MRE are the preferred modalities for detecting intra-abdominal fistulas, with CTE demonstrating a sensitivity of 70% and specificity of 97%, while MRE shows a sensitivity of 76% and specificity of 96% for diagnosing these lesions [3]. Fistulas occur in about 30% of patients with CD, with the perianal region being the most common site, where they may be classified as simple or complex [6].
Perianal fistulas are often assessed using rectal MRI to evaluate their extent and associated complications. Accurate imaging requires that the MRI encompasses the full range of the fistula tract, as the external opening is frequently found at the upper thigh level. Fat-suppressed T2-weighted and contrast-enhanced T1-weighted images are particularly effective in visualizing the extent of perianal fistulas, allowing differentiation between those with active inflammation and those that are fibrotic [6].
Internal fistulas, such as enteroenteric and enterocolic types, are often asymptomatic and may not require intervention. However, they can lead to intra-abdominal abscesses (IAAs), complicating treatment with anti-tumor necrosis factor (anti-TNF) agents, which may inhibit healing in the presence of infections [6].
Enterovesical fistulas, occurring in 2%–8% of CD patients, often manifest as recurrent urinary symptoms and typically connect to the right dome of the bladder, necessitating careful imaging evaluation, particularly using sagittal and coronal views for better detection [6].

- **Inflammatory mass**

An inflammatory mass is characterized by dense mesenteric inflammation near a bowel segment with mural inflammation, without a distinct fluid component or clear boundary. On CTE, it appears as an area of ill-defined soft tissue attenuation, while on MRE, it shows variable signal intensities interspersed with fat **(Fig.11)**. The term "phlegmon" should be avoided for describing an inflammatory mass, as it is imprecise and may lead to confusion [5].

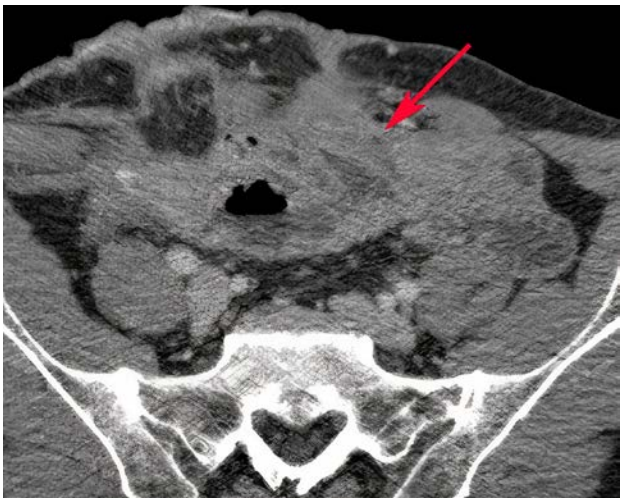

Fig.11: *Axial contrast enhanced CTE image shows small bowel wall thickening along with an adjacent enhancing mesenteric inflammatory mass (red arrow).*

- **Abscess**

An abscess in CD typically appears as a well-defined fluid collection with rim enhancement on contrast enhanced CTE or MRE, often containing internal gas. Abscesses frequently develop in locations such as the mesentery, peritoneal cavity, retroperitoneum, body wall, and perirectal or perianal regions. On diffusion-weighted imaging, abscesses exhibit restricted diffusion, showing

high signal intensity on high b-value images and low signal on ADC maps—an especially valuable feature for patients unable to receive intravenous contrast [5] **(Fig.12)**. CTE demonstrates a sensitivity of 85% and specificity of 95% in detecting abscesses, while MRE has a sensitivity of 86% and specificity of 93% [3].

Abscesses in CD patients are often connected to inflamed bowel segments via sinus tracts, and CT is particularly reliable for accurately pinpointing their location and extent. Intra-abdominal abscesses, which occur in up to 10% of Crohn's patients, may result from perforation or gastrointestinal fistulas and are usually located around the terminal ileum on the right side of the abdomen. IAAs can sometimes be misinterpreted as normal bowel tissue, especially when they are located near actively inflamed segments showing asymmetric mural hyperenhancement, particularly along the mesenteric border [6].

Management of IAAs includes antibiotics alone, antibiotics with percutaneous drainage, or antibiotics combined with surgery. Current guidelines by the European Crohn's and Colitis Organisation (ECCO) and the European Society of Colo-Proctology (ESCP) recommend treating abscesses smaller than 5 cm with antibiotics alone, while larger abscesses (>5 cm) should be managed with percutaneous drainage and antibiotic therapy avoiding surgery and preserving bowel length [6].

- **Free perforation**

  In some cases, advanced penetrating CD can cause spontaneous perforation, resulting in free air in the abdominal cavity that requires surgical evaluation [5].

■ **Appendiceal Involvement**

In cases where CD affects the appendix, patients often present with symptoms that mimic acute appendicitis or a periappendiceal abscess, posing a diagnostic challenge.

On CT imaging, appendiceal CD is characterized by wall thickening of the appendix with surrounding periappendiceal inflammation, as well as pronounced mural hyperenhancement of the adjacent bowel wall and extensive inflammation in the cecum **(Fig.13)**.

This pattern of hyperenhancement and inflammation in the cecum differs from the submucosal edema typically seen in primary acute appendicitis, providing a useful distinguishing feature.

Such imaging findings can help radiologists differentiate between CD with appendiceal involvement and primary acute appendicitis, especially in cases where the patient has no prior diagnosis of CD.

Accurate CT interpretation is critical, as it directly influences the surgical approach, guiding decisions between procedures like laparoscopic appendectomy, ileocecectomy, or delayed intervention with percutaneous drainage [6].

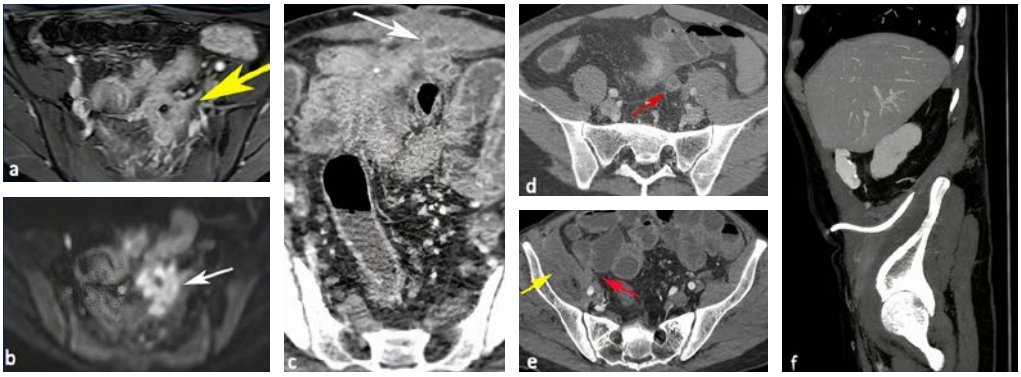

Fig.12: *Axial contrast-enhanced fat-suppressed T1-weighted (a) and diffusion-weighted (b = 800 sec/mm2) (b) MRE images show a rim-enhancing collection with gas, consistent with an abscess (arrows), with high signal intensity on the diffusion-weighted image owing to restricted diffusion. Axial contrast enhanced CTE images (c and d) show mesenteric fluid collections with rim enhancement adjacent to a thick-walled small bowel segment with inflammation, consistent with abscesses (arrows). Axial (e) and sagittal (f) contrast enhanced CTE images show a fistula (red arrow) leading to the development of an iliopsoas abscess (yellow arrow). Catheter after percutaneous drainage of the right iliopsoas abscess (f).*

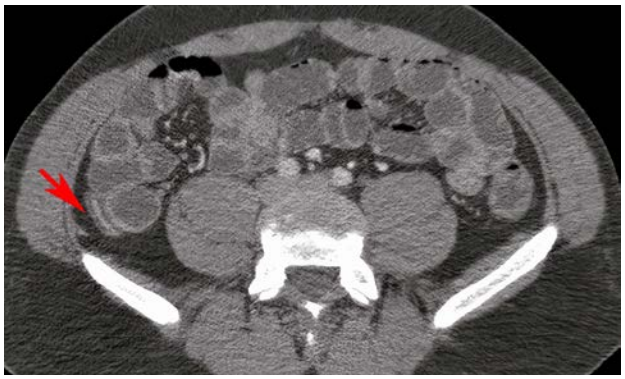

Fig.13: *Axial contrast-enhanced CTE image shows segmental mural hyperenhancement of the right colon along with submucosal edema in the cecum (arrow), suggesting inflammation of Crohn's disease.*

■ **Post-surgery Recurrence**

Post-operative reappearance of CD at the anastomosis site often occurs after intestinal removal due to a stricture, especially in individuals with ileocolonic anastomosis [8] **(Fig.14)**.

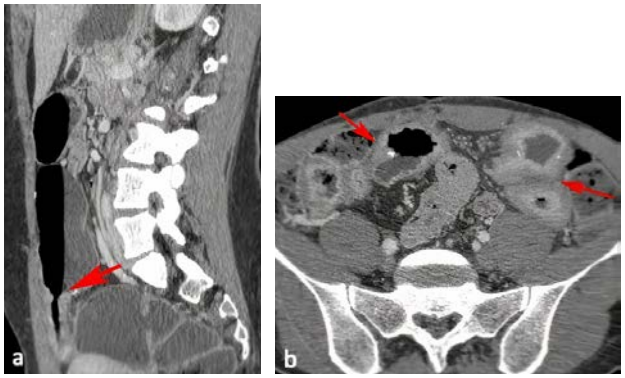

Fig.14: *Sagittal (a) and axial (b) contrast enhanced CTE image show mural thickening (red arrows) at the anastomosis site resulting in stenosis with overlying bowel dilation.*

■ **Carcinoma**

Crohn's disease-affected areas have an increased risk of developing adenocarcinoma, with individuals suffering from Crohn's colitis facing a colorectal cancer risk that is 4 to 20 times higher than that of the general population.

Additionally, bowel segments that are non-functional are also at a greater risk for cancer development. Carcinomas generally present as narrow lesions, making them difficult to differentiate from benign fibrotic strictures. Neoplastic lesions often result in longer strictures and may arise in bowel segments that exhibit no inflammation **(Fig.15)**.

The suspicion of bowel cancer is heightened when standard treatments do not relieve bowel obstruction in patients with CD [9,10].

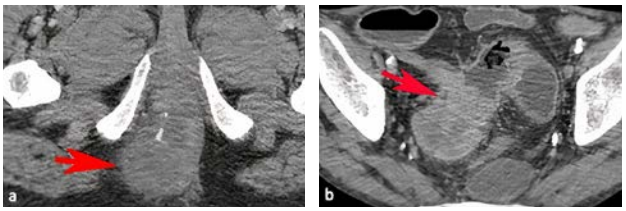

Fig.15: *Axial contrast enhanced CTE images show large masses (red arrows) arising from rectum (a) and ileum with adjacent lymphadenopathy (b). Pathology results showed that both masses were adenocarcinoma arising from segments affected by Crohn's disease.*

Conclusion

CTE and MRE are invaluable tools in evaluating the intricate and multifaceted manifestations of CD, providing detailed insights into both inflammatory and fibrostenotic changes.

These imaging modalities offer unique advantages, with CTE excelling in spatial resolution and emergency settings, while MRE, free from ionizing radiation, is ideal for longitudinal assessment, particularly in younger patients [3].

By illustrating the range of imaging features associated with active inflammation, strictures, and penetrating disease, this essay aims to serve as a practical guide for radiologists in recognizing and assessing the complications of CD. Accurate diagnosis and timely intervention are critical, as they can significantly impact patient outcomes by guiding appropriate medical or surgical treatment [11].

As our understanding of CD continues to evolve, so too must the approaches in imaging interpretation.

Ongoing research and collaboration between gastroenterologists and radiologists are essential to further refine diagnostic accuracy, ensuring that imaging not only supports clinical decision-making but also contributes to personalized care strategies.

Radiologists play a vital role in the multidisciplinary management of CD, and continuous education in imaging advancements is key to improving the long-term outlook for patients with this chronic condition.

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