

Role of MR Enterography in Assessment of Small Bowels Diseases: A Review Article

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ABSTRACT

Background: Magnetic Resonance Enterography (MRE) has evolved as a fundamental imaging modality in the assessment of small bowel diseases, thanks to its non-invasive nature and the absence of radiation exposure. It offers detailed visualization of the small bowel's morphology and function, overcoming challenges presented by the bowel's complex anatomy and physiology. MRE's ability to provide comprehensive insights into various small bowel pathologies, including inflammatory bowel diseases, tumors, and vascular disorders, underscores its significance in clinical practice. **Objective:** This review aims to elucidate the role of MRE in the diagnosis and management of common small bowel diseases, highlighting its advantages over other diagnostic methods, and discussing the indications, contraindications, and techniques employed in MRE.

Methods: A comprehensive review of scientific and medical journals was conducted using reputable search engines to get scientific data on the anatomy and histopathology of the small bowels and MR Enterography indications and contraindications, and its role in common small bowel diseases compared to other diagnostic methods such as CT and endoscopy. Only recent, relevant scientific papers were included. **Conclusion:** MRE has emerged as an essential tool in the assessment of small bowel diseases and is expected to continue playing a significant role in the future.

Keywords: Crohn's Disease, Inflammatory Bowels Diseases, Post-Chemotherapy Assessment, Small Bowels Tumors.

INTRODUCTION

MR Enterography (MRE) has become an indispensable tool in the diagnosis and monitoring of small bowel diseases. It offers a non-invasive and radiation-free approach to visualize the small bowel, providing comprehensive details about its morphology and function despite the imaging challenges posed by its lengthy and convoluted structure, constant peristaltic movement, and complex histology [1]. MRE is performed using a surface coil and requires both oral and intravenous contrast, along with bowel preparation and an antispasmodic agent. It can be conducted through a wide array of sequences, enhancing its diagnostic capabilities.

Therefore, this research aimed to examine the MRE role in the diagnosis and ongoing management of common small bowel diseases.

Methods:

Extensive scientific research was conducted across various scientific and medical journals, websites, and book publishers using the Google search engine to get scientific data on the anatomy of the small bowels and MR Enterography indications and contraindications, and its effectiveness in diagnosing and managing common small bowel diseases compared to other diagnostic methods such as CT and endoscopy.

Anatomy of the Small Intestine: The small intestine, which constitutes the most extensive segment of the digestive system, spans from the stomach's pyloric opening to the ileocecal valve. Its length ranges around 6 to 7 meters, while its diameter remains relatively slim. Small Intestine contain three parts: the duodenum, jejunum, and ileum. [3].

MR Enterography: Indications, Contraindications, and Techniques

MRE Indications; MRE is acclaimed for its diagnostic precision, especially for conditions such as Crohn's disease and other inflammatory bowel diseases, marking it as the preferred diagnostic tool. It plays a crucial role in assessing unexplained small bowel wall thickening and identifying sources of gastrointestinal bleeding. MRE is instrumental in detecting small bowel masses, strictures, fistulas, and intestinal abscesses. It also assesses small bowel obstruction and evaluates acute abdominal pain in pregnant females. Additionally, MRE is used to investigate intestinal wall tears resulting from trauma or injury [1].

MRE Contraindications; The contraindications for MRE are consistent with those for MRI devices, divided into absolute and relative categories. This classification ensures patient safety and the effectiveness of the diagnostic process [3].

MRE Techniques; In MRE, various methods are utilized to improve the precision of diagnoses:

Coils: Employing an array of multi-coil surface receivers is a widely adopted practice.

Oral Contrast Agents: The preference for biphasic oral contrast agents stems from their efficacy in generating distinct visuals in both T2-weighted (bright) and T1-weighted (dark) scans, which assist in evaluating mucosal enhancement and the thickening of the bowel wall. Commonly, agents such as 0.1% low-density barium suspension (NeuLumEX) and mannitol are used. Recent studies have identified pineapple juice as a potent medium for bowel expansion and enhancing image clarity, offering the advantage of minimal artefacts and lacking adverse reactions (**Figure 1**) [4].

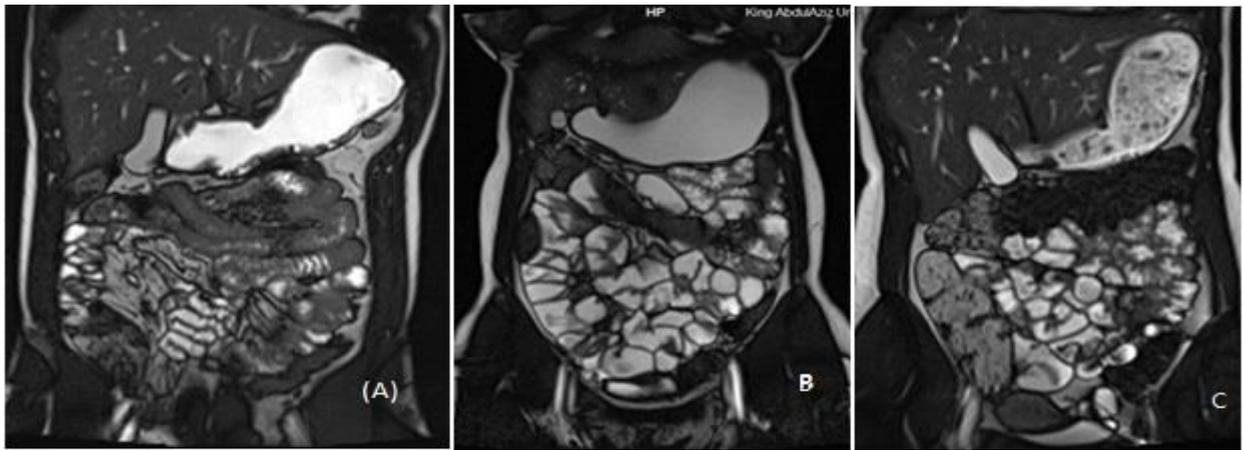


Figure 1: MRE with 3 different natural oral contrast;

Fig (1A) Coronal T2 WI MRI abdomen using 1000 ml water as an oral contrast. The small bowel loops are partially filled and poorly distended.

Fig (1B) Coronal T2 WI MRI abdomen using 1000 ml Pineapple juice as an oral contrast. It shows homogenous and uniform opacification of small bowel segments with good distension. Juice displays the best results,

Fig (1C) Coronal T2 WI MRI abdomen using 1000 ml milk as an oral contrast. It shows inhomogeneous bowel opacification with poor distension.

Intravenous Contrast Usage: Gadolinium is widely chosen for its contrast-enhancing capabilities.

Antispasmodic drugs: Compounds like Buscopan are administered to alleviate bowel spasms and minimize movement during scans.

Imaging Sequences: MRE employs an extensive range of imaging sequences to obtain intricate visuals of the small intestine. This assortment encompasses Echoplanar imaging (EPI), Rapid acquisition with relaxation enhancement (RARE), Single Shot RARE (examples include HASTE, TSE, FSE), Balanced steady-state free precession imaging (bSSFP, also known as FISP), Spoiled gradient echo imaging (referred to as FLASH, SPGR, T1FFE), 3D T1-weighted imaging techniques (like VIBE, THRIVE), Hydrographic Projection Imaging (**Figure 2**), Techniques for Fat Suppression and the Dixon method, Dynamic and Cine imaging approaches, Diffusion-weighted imaging (DWI), and Perfusion imaging techniques. Each of these sequences is selected for its specific advantages, facilitating a thorough investigation of both the structural and functional aspects of the small intestine [5].

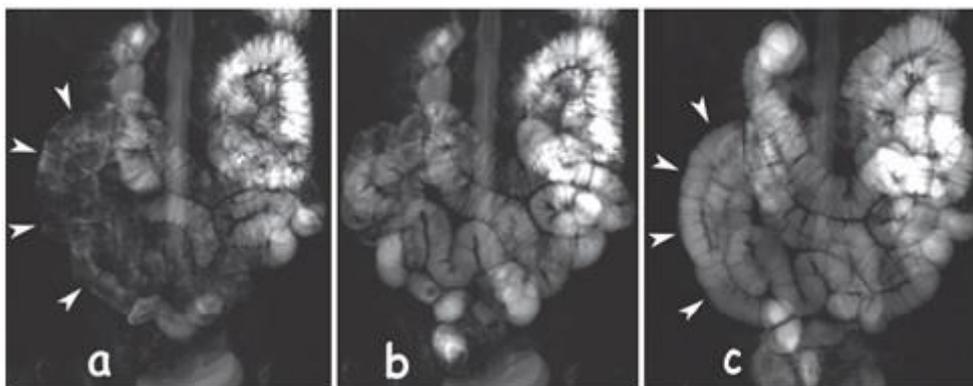


Figure 2: Hydrographic projection images captured using the HASTE technique with effective echo time of 600 milliseconds and a cross-sectional thickness of 10 cm. It shows three images (a–c) at different timepoints in a series of 60 obtained during filling of the small bowel. It is important to note the enhanced visibility of the distal ileum (indicated by arrowheads) as the small bowel continues to fill and the fluid movement within it decelerates. The use of antiperistaltic agents was unnecessary, thanks to the rapid acquisition of images in less than a second. Additionally, respiratory gating minimizes the effects of respiratory motion and misalignment, enabling the sequence to function as a "cine" feature, which assists in identifying anomalies in the small bowel [7].

MR Enterography Clinical Applications

1. Congenital Bowel Disease:

Instances of such conditions are bowel duplications, uncommon irregularities typically identified by chance as smooth, rounded structures that are either cystic or tubular, filled with fluid, and feature thin walls that may show slight enhancement. These formations can be found either connected to or situated near the gastrointestinal tract.

2. Crohn's and Inflammatory Diseases:

Crohn's Disease: This chronic inflammatory bowel disease is marked by transmural and segmental inflammation of the intestinal wall. Symptoms include weight loss, fatigue, chronic diarrhea, abdominal pain, and a positive family history.

Diagnostic signs include: Bowel Wall Thickness: Normally, the bowel wall thickness with adequately distended bowel ranges from 1 to 3 mm. Mild wall thickening is considered to be 3-5 mm, moderate is 5-9 mm, and severe is greater than 10 mm. Thickness greater than 15 mm, especially if asymmetric or mass-like, should raise suspicion for neoplasm.

Bowel Wall Enhancement: An abnormal increase in vascular permeability leads to abnormal wall enhancement in both active and fibrotic stages of the disease. Enhancement patterns may vary including mucosal-only (impacting the innermost layer of the wall), uniform (involving all layers of the bowel wall equally), stratified (impacting the mucosal and serosal layers with diminished enhancement in the center). Additional classifications encompass no notable abnormal enhancement, slight enhancement (increased beyond normal but considerably lower than vascular enhancement), moderate enhancement (elevated beyond normal yet slightly less than vascular), and significant enhancement (comparable to or exceeding the enhancement seen in nearby vascular structures) [8].

T2 Mural Signal: In T2-weighted imaging with fat saturation, heightened signal intensity of the mural region suggests the presence of mural edema and active disease, whereas increased bowel thickness coupled with a reduced T2 signal points to fibrosis. The psoas muscle serves as a comparative standard. Furthermore, the presence of fat accumulation signals long-term disease, and edema around the bowel wall signifies ongoing activity.

Ulcerations: These denote areas of active inflammation and typically exhibit heightened enhancement in post-contrast T1-weighted scans. Moderate to severe ulcerations can be observed in both T1 and T2 images, though detecting minor ulcerations

might be challenging due to their resemblance to mucosal folds.

Loss of Haustration: This condition results in the disappearance of the colon's haustral folds, leading to a uniformly smooth surface.

Comb Sign: This refers to the appearance of swollen mesenteric vessels, a marker of active inflammation.

Creeping Fat: An increase in subserosal fat thickness is indicative of chronic disease.

Skip Lesions: A hallmark of Crohn's disease, these are interspersed unaffected bowel segments [9].

MR Enterography (MRE) is also utilized in assessing complications associated with Crohn's disease such as [10]:

Stenosis: This condition is characterized by a thickening of the bowel wall alongside a reduction in the diameter of the lumen. Only severe cases of stenosis, indicated by dilation before the constriction and a moderate to significant elevation in the mural T2 signal, are recognized as a serious complication.

Infiltration: This involves the displacement of the creeping fat located between bowel segments, resulting in the bowels becoming tethered and bent. **Fistula:** Fistulas and sinus tracks are frequent complications in Crohn's disease, often showing pronounced enhancement in post-gadolinium T1-weighted scans. A fistula may appear in a "tram track" formation with layered appearances or as a linearly enhancing structure, connecting one loop of the bowel to another to another hollow organ, or to the skin). **Abscess:** In the context of severe active Crohn's disease, abscesses are typically identified by a rim of enhancement in post-gadolinium T1-weighted scans and central areas of high signal on T2-weighted scans [3, 11].

Diverticular Disease & Diverticulitis

Diverticulosis involves the formation of small pouches (diverticula) in the intestinal walls. When a diverticulum becomes inflamed or perforated, it leads to diverticulitis, potentially causing complications such as bleeding, perforation, and abscess.

3. Celiac Disease & Autoimmune Disorders:

Celiac disease is an autoimmune condition activated by consuming gluten in individuals with a genetic susceptibility. MRE observations for celiac disease are categorized into findings related to the intestines and those unrelated to the intestines [12]:

Intestinal Findings: These include fold pattern abnormalities, such as decreased jejunal folds and increased ileal folds, and in severe cases, complete

flattening of jejunal folds. Small bowel dilatation, intussusception, and intestinal strictures are also common findings.

Non-intestinal Findings: These encompass mesenteric abnormalities, such as lymph node enlargement and vascular engorgement, hyposplenism, and ascites [13].

Systemic Sclerosis: This chronic autoimmune disease affects various parts of the body, including the skin, joints, and internal organs. MRE signs include the classic "hidebound sign," small bowel sacculaton, and other findings like intestinal pseudo-obstruction and transient intussusception.

4. Small Bowel Tumors;

Intestinal polyposis syndromes, which cause the growth of multiple gastrointestinal polyps, can be benign, cancerous, or precancerous. MRE is useful for the surveillance of small bowels for the prophylactic removal of large luminal polyps. Gastrointestinal stromal tumors (GISTs), though infrequent, are the most prevalent primary GIT mesenchymal tumors. Diagnosis via MRE can be challenging, with GISTs typically appearing as smooth rounded masses that expand the small-bowel wall [14].

Neuroendocrine tumors of the GIT include carcinoid tumors, pheochromocytomas, and various location-dependent entities. Carcinoid tumors, for example, are the second most common primary small bowel malignancy and can be detected on MRE as avidly enhancing, well-delimited submucosal masses [15].

Lymphoma accounts for a significant portion of small bowel malignancies and GIT lymphomas, with MRE revealing a variable appearance that includes preservation of adjacent fat tissue and involvement of long or multiple segments. Primary small bowel adenocarcinoma is the most common primary tumor of the small intestine, with MRE showing moderately enhancing masses or lesions that may cause luminal narrowing [16].

5. Post-Operative / Therapy Follow- Up [17]

Radiation therapy and chemotherapy can lead to small bowel inflammation (therapy-induced enteritis), with severity depending on the dose, type, and patient's risk factors. MRE findings vary, but main observations include wall thickening, edema, stricture, obstruction, deep ulceration, and fistulation to adjacent organs (**Figure 3**). Accurate imaging is crucial for surgical planning, particularly for treating obstructive symptoms related to strictures [17].



Figure 3: Enterovesical fistula. Balanced FFE or True FSIP Coronal image, yellow arrow shows enterovesical fistula. Post-contrast T1WI post contrast image shows small bowel tense enhancement with fistula tram track appearance.

Peritoneal adhesions, a potential outcome of abdominal surgery, can lead to various complications, including acute inflammatory and fibrostenotic strictures, with MRE providing detailed imaging for assessment and management planning.

6. Small Bowel Obstruction (SBO):

MRE is adept at identifying both intermittent and low-grade small bowel obstructions, which are typically challenging to detect. Achieving optimal small bowel distension with intraluminal contrast material is crucial to enhance the visibility of stenosis regions [19].

7. Vascular/Ischemic Diseases:

Bowel ischemia occurs when the blood supply to the small bowel is diminished or halted, potentially causing bowel wall damage and, in severe cases, tissue necrosis. Common causes include thromboembolism, non-occlusive ischemia, bowel obstruction, neoplasms, inflammatory conditions, effects of chemotherapy and radiation therapy, and vasculitis. MRE findings for bowel ischemia, which vary based on the condition's severity, often include bowel wall thickening, diminished enhancement (a highly specific sign), low-grade obstruction, and the "target sign," which shows alternating layers of high and low signal intensity [20].

8. Infectious Diseases:

Infectious diseases of the small bowel can stem from viral, bacterial, and parasitic agents. In cases of tuberculosis (TB), MRE findings are generally nonspecific, but characteristic features may include involvement of the ileocecal junction (the most common finding), mural thickening of bowel loops, and lymphadenopathy, often with necrotic changes. Other notable MRE findings in TB cases include splenic granuloma, spondylodiscitis with prevertebral abscess, and sealed small bowel perforations with collections and air-fluid levels. The presence of

clinical history or a positive tuberculin skin test can aid in making a more accurate diagnosis [21].

9. Gastrointestinal (GIT) Bleeding:

Acute GIT bleeding necessitates immediate stabilization and resuscitation, limiting the role of MRE in such emergencies. However, in cases of occult chronic GI bleeding, which is a leading cause of iron deficiency anemia, and obscure GI bleeding, where the source remains unidentified after endoscopy, MRE can be useful. These conditions are often rooted in the small bowel and may present with symptoms of anemia [21].

10. Abdominal Pain in Pregnancy [22]:

Abdominal pain is a frequent complaint among pregnant women, with causes ranging from gynecological to gastrointestinal and beyond. While ultrasound remains the first-line imaging modality, MRE is becoming more favored for its diagnostic precision, rapid acquisition times, and safety profile. The preferred MRE technique in pregnancy involves Triplane T2-weighted images with and without fat saturation, avoiding oral contrast. The use of gadolinium is discouraged due to potential risks to the fetus [23]. Abdominal pain during pregnancy can stem from various causes, with gastrointestinal (GIT) issues being a significant contributor. Appendicitis tops the list as the most frequent GIT-related cause. Other conditions include inflammatory bowel disease (IBD) and small bowel obstruction. Genitourinary problems such as hydronephrosis and pyelonephritis, as well as gynecological issues like ovarian torsion, adnexal

masses, and leiomyoma, also play a role. Vascular concerns, including venous thromboembolic disease, are additional factors to consider [22].

Comparison MR Enterography and other diagnostic methods

Within the spectrum of diagnostic approaches, MRE is distinguished as a non-invasive imaging method that provides exceptional insight into the small intestine. It enables the evaluation of wall thickness, enhancement of the mucosa, strictures, fistulas, and abscesses, all without resorting to ionizing radiation. This aspect renders it an ideal option for ongoing surveillance. MRE is acclaimed for its outstanding ability to contrast soft tissue more effectively than other imaging techniques, thereby improving the delineation of the small intestine's wall and adjacent structures. Additionally, its capacity for multiplanar imaging facilitates comprehensive assessments of intricate disease mechanisms and the spatial relationships of anatomical structures. Each diagnostic method offers unique advantages and limitations. Capsule endoscopy is notably effective for identifying mucosal lesions, while CT Enterography (CTE) is favored for its rapid acquisition and widespread availability. A small bowel follow-through (SBFT) is considered cost-effective for assessing small bowel transit and anatomical abnormalities (Figure 4). Radiologists must weigh the pros and cons of each modality, taking into account the specific disease and patient characteristics, such as age, gender, and clinical status, to choose the most suitable test for each individual [24].

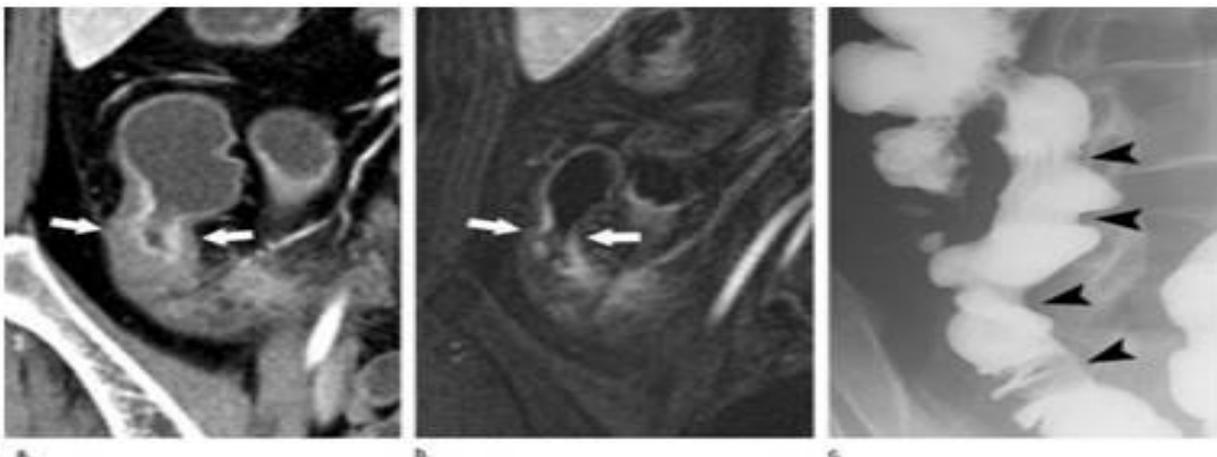


Figure 4: CTE, MRE, SBFT of Terminal Ileum Active Crohn's

(a) CT Enterography. (b) T1W MRI Enterography. (c) Small bowel Follow through

Below are algorithms for diagnosing small bowel diseases using MR enterography (Figure 5 - 8):

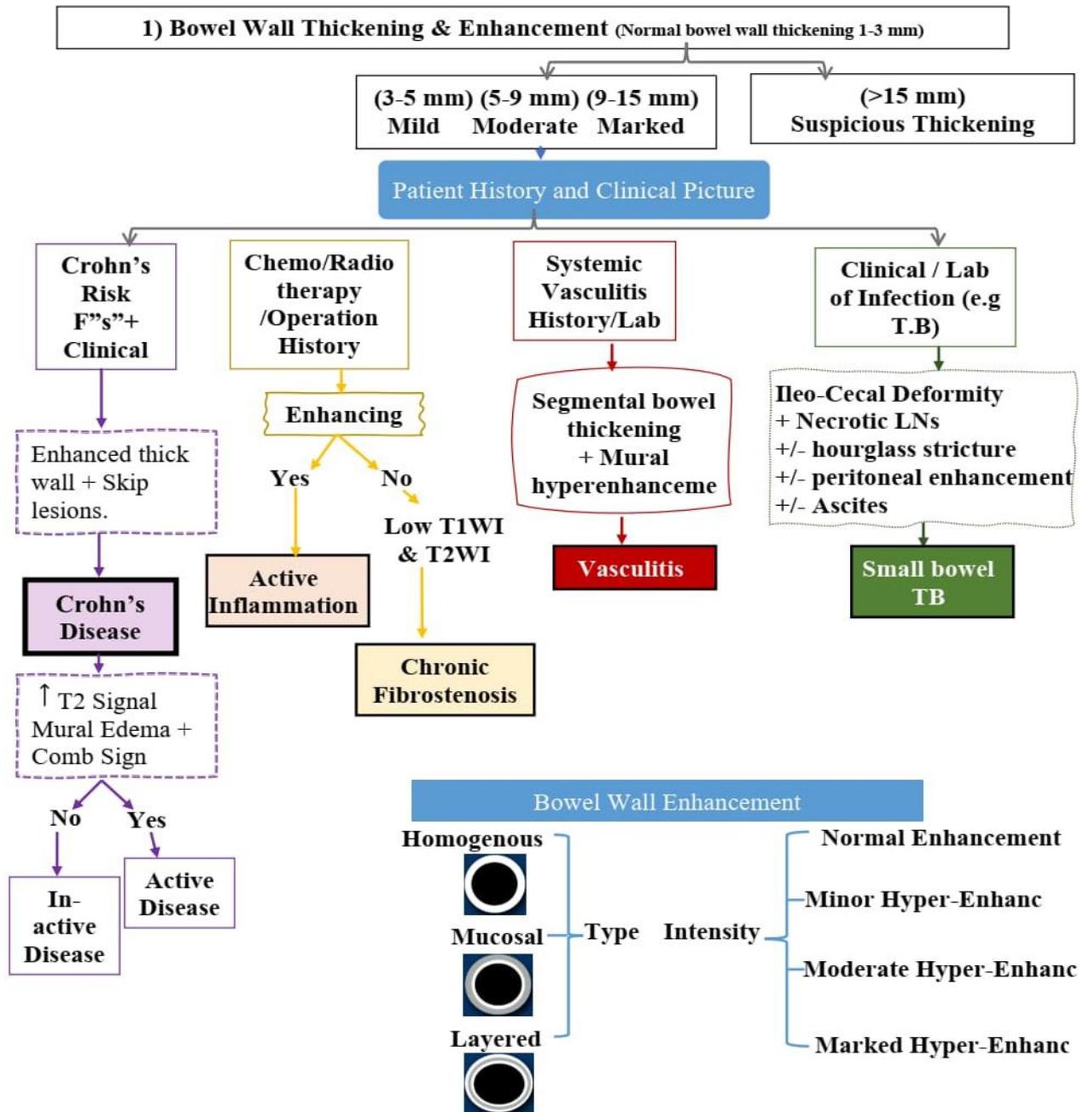


Figure 5: Bowel wall thickening and enhancement ranging from 3 to 15 mm

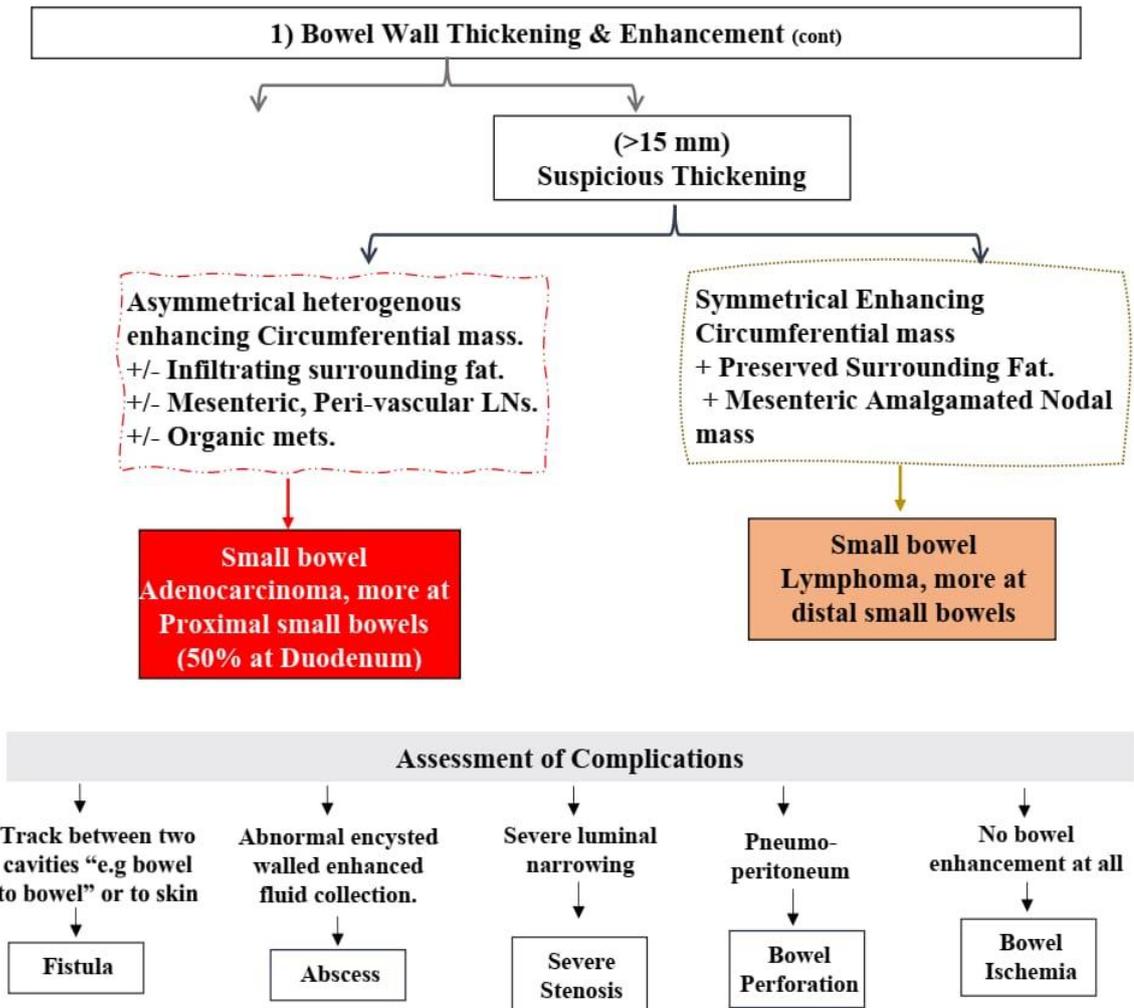


Figure 6: Bowel wall thickening and enhancement greater than 15 mm.

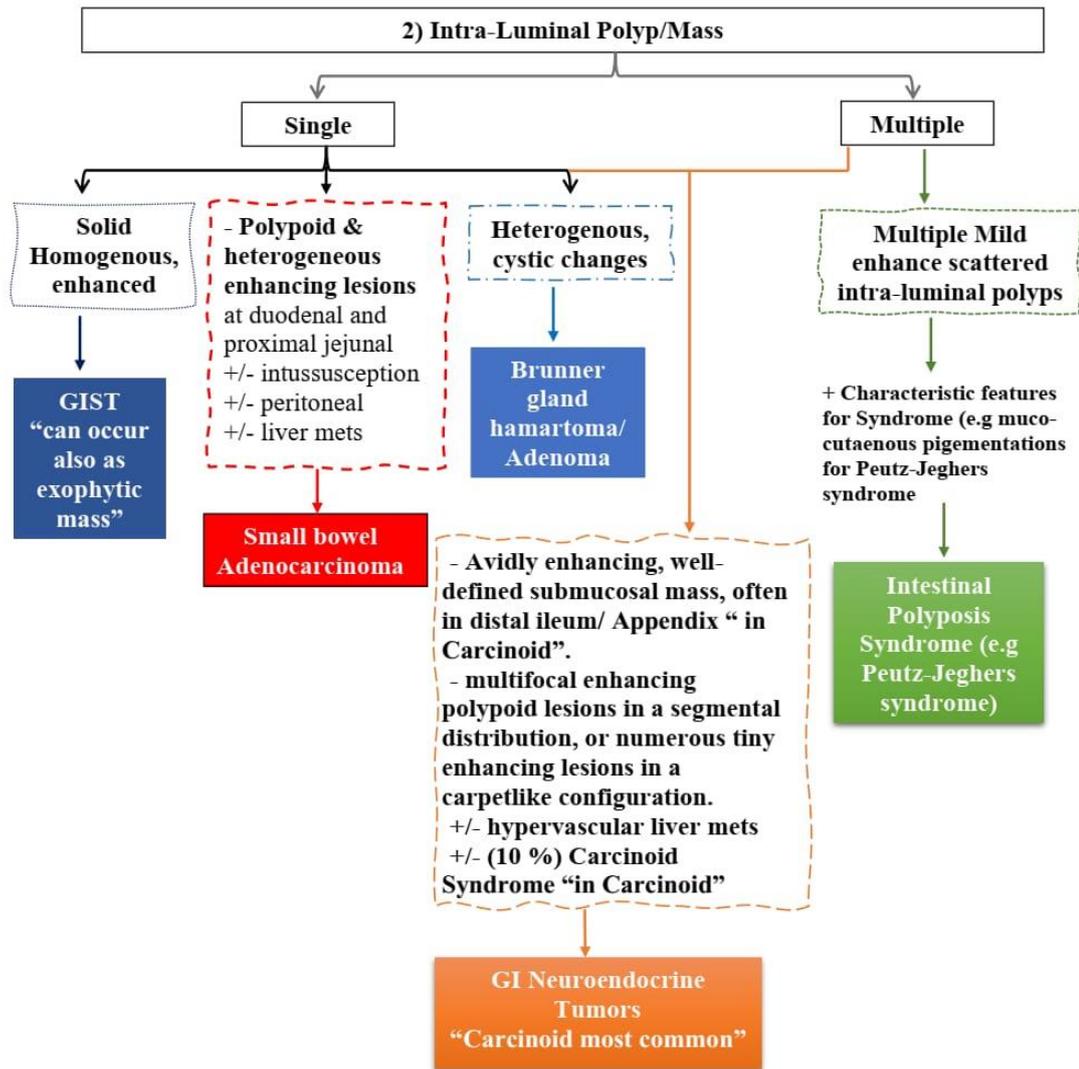


Figure 7: Intra-Luminal Polyp/Mass.

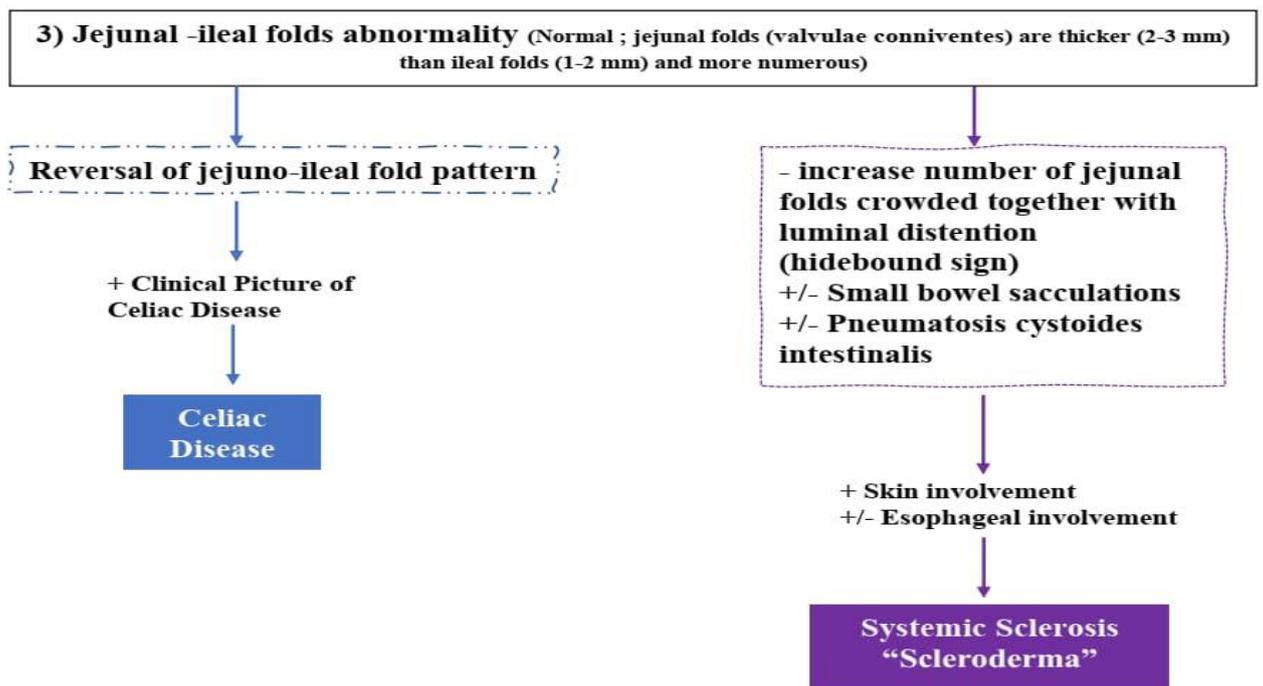


Figure 8: Jejunal-ileal folds abnormality

CONCLUSION

In conclusion, MRE has proven to be an indispensable diagnostic and monitoring tool for small bowel diseases. It's a non-invasive, radiation-free approach allows for comprehensive visualization and detailed analysis of the small bowel's morphology and function, overcoming challenges posed by the organ's intricate anatomy, constant peristaltic movements, and complex histology. MRE is particularly beneficial for a range of conditions including inflammatory bowel diseases (notably Crohn's disease), unexplained small bowel wall thickening, gastrointestinal bleeding, and the detection of masses, strictures, fistulas, and abscesses. It also plays a crucial role in assessing acute abdominal pain in pregnant patients. Although MRE is generally safe, it does have contraindications, which are categorized as either absolute—such as active magnetic, electrical, mechanical, and metallic implants—or relative, including coronary and peripheral artery stents. The procedure employs a multicoil surface coil and necessitates the use of both oral and intravenous contrast, alongside thorough bowel preparation and an antispasmodic agent. MRE utilizes a diverse array of sequences, including EPI, RARE, HASTE, bSSFP, FLASH, THRIVE, Projection Imaging, Fat Suppression and Dixon technique, dynamic and cine imaging, DWI, and perfusion techniques.

MRE's utility in diagnosing and monitoring common small bowel diseases, especially chronic conditions like Crohn's disease, is unparalleled. MRE offers unique and irreplaceable advantages compared with other diagnostic methods. Consequently, it has emerged as a critical tool in the assessment of small bowel diseases and is expected to maintain and possibly expand its pivotal role in future medical practices.

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REFERENCES

1. **Pierro A, Minordi L, Larosa L et al. (2023):** Small Bowel Imaging from Stepchild of Roentgenology to MR Enterography: Part I: Guidance in Performing and Observing Normal and Abnormal Imaging Findings. *Life (Basel)*, 13: 1691.
2. **Vallicelli C, Coccolini F, Catena F et al. (2011):** Small bowel emergency surgery: literature's review. *World J Emerg Surg.*, 6: 1.
3. **Ram R, Sarver D, Pandey T, Guidry C, Jambhekar K (2016):** Magnetic resonance enterography: A stepwise interpretation approach and role of imaging in management of adult Crohn's disease. *Indian J Radiol Imaging*, 26: 173-84.
4. **Elsayed N, Alsalem S, Almugbel S, Alsuhaime M (2015):** Effectiveness of natural oral contrast agents in magnetic resonance imaging of the bowel. *The Egyptian Journal of Radiology and Nuclear Medicine*, 46(2), 287–292. <https://doi.org/https://doi.org/10.1016/j.ejnm.2015.03.007>
5. **Bohra A, Vasudevan A, Kutaiba N, Van Langenberg D (2022):** Challenges and Strategies to Optimising the Quality of Small Bowel Magnetic Resonance Imaging in Crohn's Disease. *Diagnostics*, 12: 2533.
6. **Amzallag-Bellenger E, Oudjiti A, Ruiz A, Cadiot G, Soyer P, Hoeffel C (2012):** Effectiveness of MR enterography for the assessment of small-bowel diseases beyond Crohn disease. *Radiographics*, 32: 1423-44.
7. **David J (2010):** MRI of the Gastrointestinal Tract; Coils, Sequences, Techniques. In *MRI of the Gastrointestinal Tract*: Springer International Publishing, Ppl: 1-19.
8. **Cushing K, Higgins P (2021):** Management of Crohn Disease: A Review. *JAMA*, 325: 69-80.
9. **Mainenti P, Castiglione F, Rispo A (2021):** MR-enterography in Crohn's disease: what MRE mural parameters are associated to one-year therapeutic management outcome? *Br J Radiol.*, 94: 20200844.
10. **Moy M, Sauk J, Gee M (2016):** The Role of MR Enterography in Assessing Crohn's Disease Activity and Treatment Response. *Gastroenterol Res Pract.*, 81: 686 - 95.
11. **Griffin N, Grant L, Anderson S (2012):** Small bowel MR enterography: problem solving in Crohn's disease. *Insights Imaging*, 3: 251-63.
12. **Fasano A, Catassi C (2012):** Clinical practice. Celiac disease. *N Engl J Med.*, 367: 2419-26.
13. **Radmard A, Hashemi Taheri A, Salehian Nik E (2017):** MR enterography in nonresponsive adult celiac disease: Correlation with endoscopic, pathologic, serologic, and genetic features. *J Magn Reson Imaging*, 46: 1096-106.
14. **Shussman N, Wexner S (2014):** Colorectal polyps and polyposis syndromes. *Gastroenterol Rep (Oxf)*, 2: 1-15.
15. **Basendowah M, Ashour M, Hassan A (2021):** Multiple Small Intestinal Neuroendocrine Tumors With Findings of Intestinal Obstruction. *Cureus*, 13: e17629.
16. **Lo Re G, Federica V, Midiri F et al. (2016):** Radiological Features of Gastrointestinal Lymphoma. *Gastroenterol Res Pract.*, 2016;2016:2498143. doi: 10.1155/2016/2498143
17. **Tolan D, Taylor S, Halligan S (2010):** MRI of the Small Bowel: Clinical Role. In: *MRI of the Gastrointestinal Tract*, J. Stoker, Ed., Berlin, Heidelberg: Springer Berlin Heidelberg, Pbl. 149–171.
18. **Tryggvason G, Gíslason H, Magnússon M, Jónasson J (2005):** Gastrointestinal stromal tumors in Iceland, 1990-2003: the icelandic GIST study, a population-based incidence and pathologic risk stratification study. *Int J Cancer*, 117: 289-93.
19. **Ilangovan R, Burling D, George A, Gupta A, Marshall M, Taylor S (2012):** CT enterography: review of technique and practical tips. *Br J Radiol.*, 85: 876-86.
20. **Krishna S, Kalra N, Singh P, Kochhar R, Gupta R, Singh R, Khandelwal N (2016):** Small-Bowel Tuberculosis: A Comparative Study of MR Enterography and Small-Bowel Follow-Through. *American Journal of Roentgenology*, 207: 571-7.
21. **Kim B, Li B, Engel A, Samra J, Clarke S, Norton I, Li A (2014):** Diagnosis of gastrointestinal bleeding: A practical guide for clinicians. *World J Gastrointest Pathophysiol.*, 5: 467-78.
22. **Ali A, Beckett K, Flink C (2020):** Emergent MRI for acute abdominal pain in pregnancy—Review of common pathology and imaging appearance. *Emergency Radiology*, 27: 205-14.
23. **Dhamecha R, Pajai S, Bhasin T (2023):** Acute Abdomen in Pregnancy: A Comprehensive Review of Diagnosis and Management. *Cureus*, 15: e40679.
24. **Laghi A, Hara A (2018):** Small Bowel Disease. In: *Hodler J, Kubik-Huch RA, von Schulthess GK, editors. Diseases of the Abdomen and Pelvis 2018-2021: Diagnostic Imaging - IDKD Book*. 4. Cham: Springer International Publishing, Pbl: 117-22.