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Does MR enterography offer added value after a recent CT in the evaluation of abdominal pain in Crohn's disease patients?

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ABSTRACT

Purpose: To determine if there is added value in performing MR enterography shortly after a contrast-enhanced CT of the abdomen and pelvis in patients with Crohn's disease presenting with acute abdominal pain.

Materials and methods: A total of 45 consecutive patients who underwent MRE examination < 7 days after a CT met our strict inclusion criteria. Independent and blinded review of both MRE and CT exams was performed by two abdominal radiologists.

Results: There were no significant differences in detection of various findings associated with Crohn's disease between modalities. These findings included abscess, fistula, bowel wall thickening, free fluid, stricture, and bowel obstruction. There was moderate interobserver agreement with CT (Kappa: 0.52, 95% CI: [0.4–0.6]) and fair with MRE (Kappa: 0.36, 95% CI:[0.3 = 0.5]).

Conclusion: The routine use of MRE after a diagnostic CT should be avoided, as it provides no additional valuable information, at the expense of extra patient risks, discomfort, and higher health care costs.

1. Introduction

In the emergency department, computed tomography (CT) is the workhorse of diagnostic imaging for patients presenting with abdominal pain, as it allows for rapid and efficient evaluation. It plays a pivotal role in the diagnosis and management of Crohn's disease patients, who frequently present with nonspecific abdominal complaints [1]. However, it has been shown that about 1 in 10 of these patients may be exposed to harmful levels of diagnostic medical radiation due to repeated CT scanning in this young patient population [2]. Magnetic resonance imaging (MRI) offers a promising alternative.

Although not routinely utilized in the acute setting, recent advances in MRI including faster sequences and increased availability have allowed for its concomitant use alongside CT in the diagnosis and problem solving of certain clinical scenarios. Studies performed in patients with acute abdominal pain, specifically for renal colic and pancreatitis, have shown no added diagnostic value for the use of additional MRI in the acute setting [3,4].

Recently, we have seen a trend in the use of magnetic resonance enterography (MRE) as a short term follow-up exam after initial diagnostic CT in patients with Crohn's disease, despite many of the patients showing no signs of clinical deterioration. MRE is often ordered as a "reflex" next step in patient management. Some clinicians and radiologists may assume that MRI can delineate pathology more clearly and identify findings inconspicuous on CT, which is supported by the literature [5–7]. However, no universal agreement exists. In fact, some studies show that while MRI and CT may have similar sensitivities for detecting active small bowel inflammation, the optimal image quality is more consistent with CT [8]. Although it is well established that MRI has superior soft tissue contrast, it is unclear if it provides additional diagnostic value in the short term after a contrast enhanced CT. The purpose of this study is to determine if there is added value in performing MRE shortly after CT in patients with Crohn's disease presenting with abdominal pain.

2. Materials and methods

This study was HIPAA compliant with a waiver of informed consent approved by the Human Investigation Committee at our institution.

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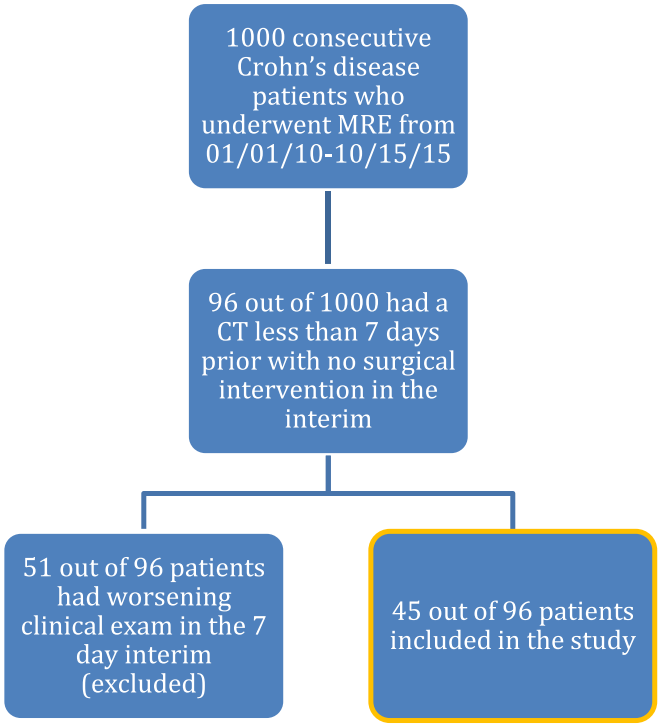


Fig. 1. Flowchart of patient selection process.

2.1. Patient selection

A search using Montage Enterprise Software (Montage Healthcare Solutions, Philadelphia, PA, USA) identified 1000 consecutive Crohn's disease patients who underwent an MRE examination for abdominal pain from January 1st, 2010 to October 15th, 2015 in our healthcare system. Each record was then individually reviewed by a radiology fellow (XX) to include only those studies that were preceded by a contrast enhanced CT examination, performed no > 7 days prior to the MRE. A total of 96 patients who already had contrast-enhanced CTs within 7 days and did not undergo any surgical intervention were identified. Out of those patients, 51 had acute exacerbations or worsening exam in the interim (reported as either worsening abdominal pain, increased nausea/vomiting, increased white blood cell count, or new elevation of lactate and identified by the radiology fellow in the electronic medical records) and thus were excluded from the study. This resulted in a total of 45 patients that met our inclusion criteria (Fig. 1).

2.2. MR enterography technique

To achieve optimal bowel distention all patients were instructed to drink three 450 mL bottles of VoLumen (a barium sulphate suspension, 0.1% w/v, 0.1% w/w; E-Z-EM, Inc.) over the course of 90 min prior to the examination. MR enterography was performed on various Siemens 1.5-T magnet scanners (Siemens Magnetom Vision, Erlangen, Germany). Patients were imaged in the supine position with a 16-channel torso array coil using the following sequences (standard TR and TE provided below): axial and coronal HASTE (Half-Fourier Acquisition Single-shot Turbo spin Echo imaging; TR = 1000 ms, TE = 90 ms (axial), TE = 81 ms (coronal)), TrueFISP (True fast imaging with steady state precession; TR = 3.72 ms, TE = 1.52 ms), and fat suppressed axial HASTE (TR = 1000 ms, TE = 90 ms). One milligram of IV Glucagon (Glucagon 1 mg/mL; Novo Nordisk, Paris, France) was then administered to reduce bowel peristalsis. Precontrast and post contrast breath-hold fat suppressed T1-weighted images (VIBE: volumetric interpolated breath-hold examination) in the axial (TR = 4.52 ms, TE = 2.39 ms) and coronal (TR = 4.09 ms, TE = 1.91 ms) planes were performed utilizing a 60 s delay. Axial diffusion weighted imaging was also obtained (TR = 5100 ms, TE = 83 ms). Various gadolinium-based contrast agents calculated for body weight (0.1 cc/kg) were used over the course of the study.

2.3. CT technique

All CT examinations were performed on MDCT scanners (GE Healthcare and Siemens) using automatic tube current modulation. The CT parameters varied but all cases were performed using 120 kVp with images reconstructed to 5 mm slice thickness in the axial and coronal planes. CT exams were performed with IV and oral contrast (n = 35) or IV contrast only (n = 10). A total of 100 mL of iohexol (Omnipaque 350, GE Healthcare) (n = 22) or 80 cc of iohexol (Omnipaque 300, GE Healthcare) (n = 23) was administered at 2–3 mL/s using bolus tracking with a scan delay of 70 s. Patients were asked to consume at least 500 cc of oral contrast as dilute (3%) Omnipaque 300 (n = 33) or 2% barium sulfate (Readi-Cat, EZ-EM) (n = 2) starting 1 h prior to the exam.

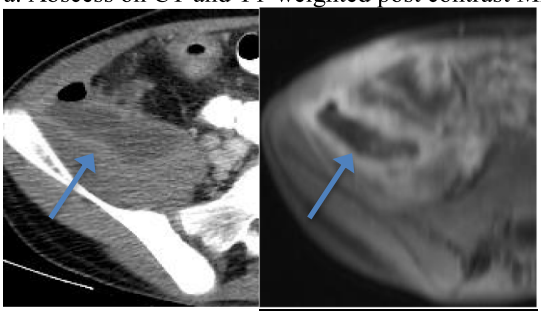
2.4. Imaging analysis

Both MRE and CT studies were randomized and separately examined by two fellowship trained abdominal radiology attendings (XX and XX) with 17 and 3.5 years of experience, respectively, on a PACS system (Synapse, Fuji Medical Systems). Specifically, CT and MRE examinations from the same patient were blinded and randomized to ensure an objective independent interpretation by both study radiologists. The readers were also blinded to all clinical information, original exam interpretation, and comparison studies to ensure objectivity. Each examination was evaluated for the presence or absence of the following findings (the definitions of which were presented to the readers and listed in Table 1): abscess, phlegmon, fistula, bowel wall thickening, mural hyperenhancement, free fluid, pneumoperitoneum, stricture, engorged vasa recta, and bowel obstruction. Results were tabulated in Microsoft Excel for comparison. Fig. 2 demonstrates examples of the above findings on CT and MRE.

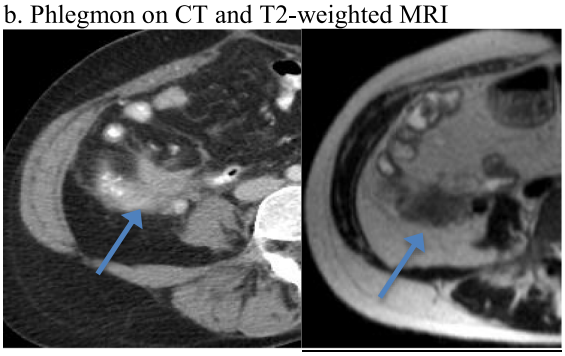
Table 1
Evaluated pathologic findings and their definitions, as adapted by the authors and used by the readers.

Pathologies	Definition
Abscess	Rim enhancing fluid collection, with or without gas
Phlegmon	Region of contrast enhancement in the fat adjacent to the bowel without a discrete fluid collection
Fistula	Structure arising from bowel and connecting with an adjacent bowel loop or other organ
Wall thickening	Bowel wall thickness > 3 mm, with adequate bowel distention
Mural hyperenhancement	Bowel wall enhancement greater than that of adjacent bowel segments
Free fluid	Free fluid in the peritoneal cavity
Pneumoperitoneum	Extraluminal air in the peritoneal cavity
Stricture	Fixed region of bowel narrowing
Engorged vasa recta (Comb Sign)	Increased perfusion/enhancement of the vasa recta
Bowel obstruction	Small bowel distention > 3 cm and large bowel distention > 6 cm with a transition point

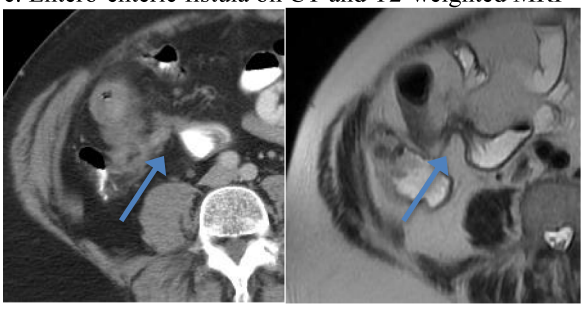
a. Abscess on CT and T1-weighted post contrast MRI



b. Phlegmon on CT and T2-weighted MRI



c. Entero-enteric fistula on CT and T2-weighted MRI



d. Stricture in the sigmoid colon on CT and axial FISP on MRI

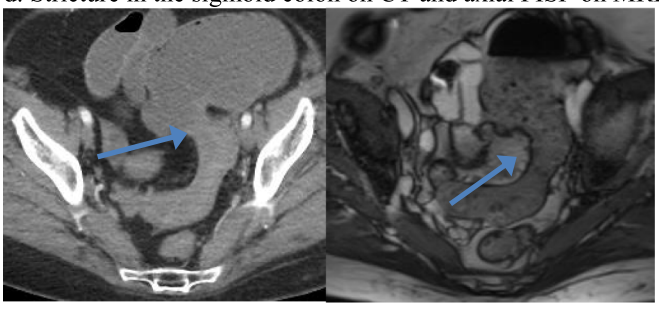
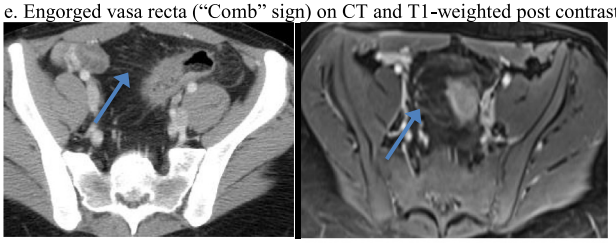


Fig. 2. Imaging examples of evaluated findings on CT and MRI.
a. Abscess on CT and T1-weighted post contrast MRI.
b. Phlegmon on CT and T2-weighted MRI.
c. Entero-enteric fistula on CT and T2-weighted MRI.
d. Stricture in the sigmoid colon on CT and axial FISP on MRI.
e. Engorged vasa recta ("Comb" sign) on CT and T1-weighted post contrast MRI.
f. Bowel wall thickening on CT and T2-weighted MRI.

e. Engorged vasa recta ("Comb" sign) on CT and T1-weighted post contrast MRI



f. Bowel wall thickening on CT and T2-weighted MRI

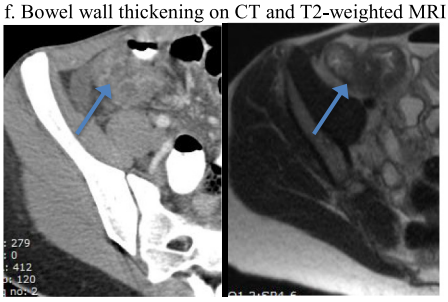


Fig. 2. (*continued*)

2.5. Statistical analysis

Statistical analysis was performed using R (The R Foundation for Statistical Computing, Version 3.3.2, 2016). Agreement between readers and techniques, overall and by finding, was assessed using Kappa tests. Agreement values were considered as follows: < 0: no agreement; 0–0.20: slight agreement; 0.21–0.40: fair agreement; 0.41–0.60: moderate agreement; 0.61–0.80: substantial agreement; 0.81–1: almost perfect agreement. The number of findings per subject was also examined comparing between readers and techniques using a paired *t*-test.

3. Results

There was overall moderate interobserver agreement with CT (Kappa: 0.52, 95% CI: [0.4–0.6]) and fair with MRE (Kappa: 0.36, 95% CI: [0.3 = 0.5]). There was moderate overall agreement between CT and MRE for Radiologist A (Kappa: 0.52, 95% CI: [0.4–0.6]) and fair agreement for Radiologist B (Kappa: 0.37, 95% CI: [0.3–0.5]). We also examined agreement by finding (see Table 2) with results varying depending on the finding. We found the best agreement (moderate or better) for abscess and fistula. Bowel wall thickening, free fluid, stricture, and bowel obstruction also demonstrated significant agreement. Pneumoperitoneum and engorged vasa recta had no significant agreement between reviewers or modalities. The other findings (phlegmon and mural hyperenhancement) had mixed findings due in part to relatively lower inter-rater agreement.

We also compared acute findings per subject using paired *t*-tests. We found no significant difference in the per subject number of acute findings using CT between Radiologist A (mean: 2.4; std. dev: 1.7) and Radiologist B (mean: 2.5; std. dev: 1.6, p = 0.36). However, there was a significant difference in the number of findings identified between Radiologist A (mean: 2.0; std. dev: 1.9) and Radiologist B using MRE (mean: 3.1; std. dev: 2.4; p = 0.0001). To test the null hypothesis of whether short term MR enterography differed in detection rates for these acute findings, we compared between modalities (CT and MRE) using the paired *t*-test and found no significant difference for either radiologist (A: p = 0.15; B: p = 0.08). Examples of same and different findings are illustrated in Figs. 3 and 4, respectively.

4. Discussion

The value of CT in management of Crohn's disease has long been

Table 2
Interrater and intermodality agreement, by finding, with Cohen's Kappa and P values.

	Abscess		Phlegmon	
	Kappa		Kappa	
Rater 1: CT vs MR	0.64	Substantial	0.73	Substantial
Rater 2: CT vs MR	0.57	Moderate	0.10	Slight
CT: interrater	0.45	Moderate	0.45	Moderate
MR: interrater	0.62	Substantial	0.23	Fair
	Fistula		Wall thickening	
	Kappa		Kappa	
Rater 1: CT vs MR	0.49	Moderate	0.56	Moderate
Rater 2: CT vs MR	0.76	Substantial	0.29	Fair
CT: interrater	0.69	Substantial	0.47	Moderate
MR: interrater	0.44	Moderate	0.38	Fair
	Mural hyper-enhancement		Free fluid	
	Kappa		Kappa	
Rater 1: CT vs MR	0.34	Fair	0.43	Moderate
Rater 2: CT vs MR	0.02	Slight	0.44	Moderate
CT: interrater	0.40	Moderate	0.44	Moderate
MR: interrater	0.43	Moderate	0.26	Fair
	Pneumoperitoneum		Stricture	
	Kappa		Kappa	
Rater 1: CT vs MR	−0.02	No	0.43	Moderate
Rater 2: CT vs MR	−0.03	No	0.41	Moderate
CT: interrater	0.66	Substantial	0.55	Moderate
MR: interrater	−0.02	No	0.40	Moderate
	Engorged vasa recta (Comb Sign)		Bowel obstruction	
	Kappa		Kappa	
Rater 1: CT vs MR	0.18	Slight	0.55	Moderate
Rater 2: CT vs MR	0.14	Slight	0.39	Fair
CT: interrater	0.28	Fair	0.81	Almost perfect
MR: interrater	0.36	Fair	0.64	Substantial

established [9] and reaffirmed over the years, with newer techniques such as CT enterography [10,11]. In the emergency room, CT is frequently the first line imaging modality in evaluating patients with Crohn's disease who present with abdominal pain, since it has been shown to be accurate in diagnosis [12]. MRE has also been shown to be useful in evaluating patients with Crohn's disease [13–16].

Our study demonstrated that there was no significant statistical difference in depicting abscess, fistula, bowel wall thickening, free fluid, stricture, and bowel obstruction in patients with Crohn's disease who had undergone a contrast-enhanced CT followed by MRE. It was presumed that contrast enhanced MR examinations such as MREs would offer additional information compared to noncontrast CTs and therefore the latter were excluded from this study. No agreement or statistical significance could be demonstrated for other findings, including phlegmon, mural hyper-enhancement, pneumoperitoneum, and engorged vasa recta. This may be due to several factors. First, we had a relatively small sample size due to our strict inclusion criteria, which may have hampered our ability to demonstrate statistical significance. Second, findings such as pneumoperitoneum are well known to be more easily be detected on CT rather than MR. Third, our two readers have a noticeable difference in experience (17 years vs 3.5 years) that likely impacted their ability and confidence in detecting various findings, particularly on MRE, and thus lowering interrater agreement.

There is great variability and inconsistency in results of similar studies in the literature. For example, a study by Low et al. [17] shows that MRI is superior to CT in depicting segments of bowel with only mild changes and wall thickening in patients with Crohn's disease, however the study sample was low at only 26 patients. On the other hand, a study by Schmidt et al. [18] demonstrates that CT has better sensitivity and higher interobserver agreement in detecting small bowel pathology compared to MRI in Crohn's disease patients, however the authors state that optimal bowel distention could not be achieved on MR. The degree of bowel dilatation is arguably the single most important factor in the ability to identify small bowel pathology on any cross-sectional modality, thus clearly affecting final results. In our study, all patients received oral preparation with VoLumen before completing the MR examination in the attempts to achieve sufficient bowel distention.

There are limitations to our study. First, all exams were reviewed by fellowship trained abdominal radiologists, specifically assessing for the above findings and therefore the results may not be applicable to a general radiology practice. Due to the retrospective nature of this study, specific imaging protocols and administration of contrast were not standardized across all exams, as we studied patients over the course of five years. To minimize variability in image parameters only MR enterographies were included, as they have all been performed with our

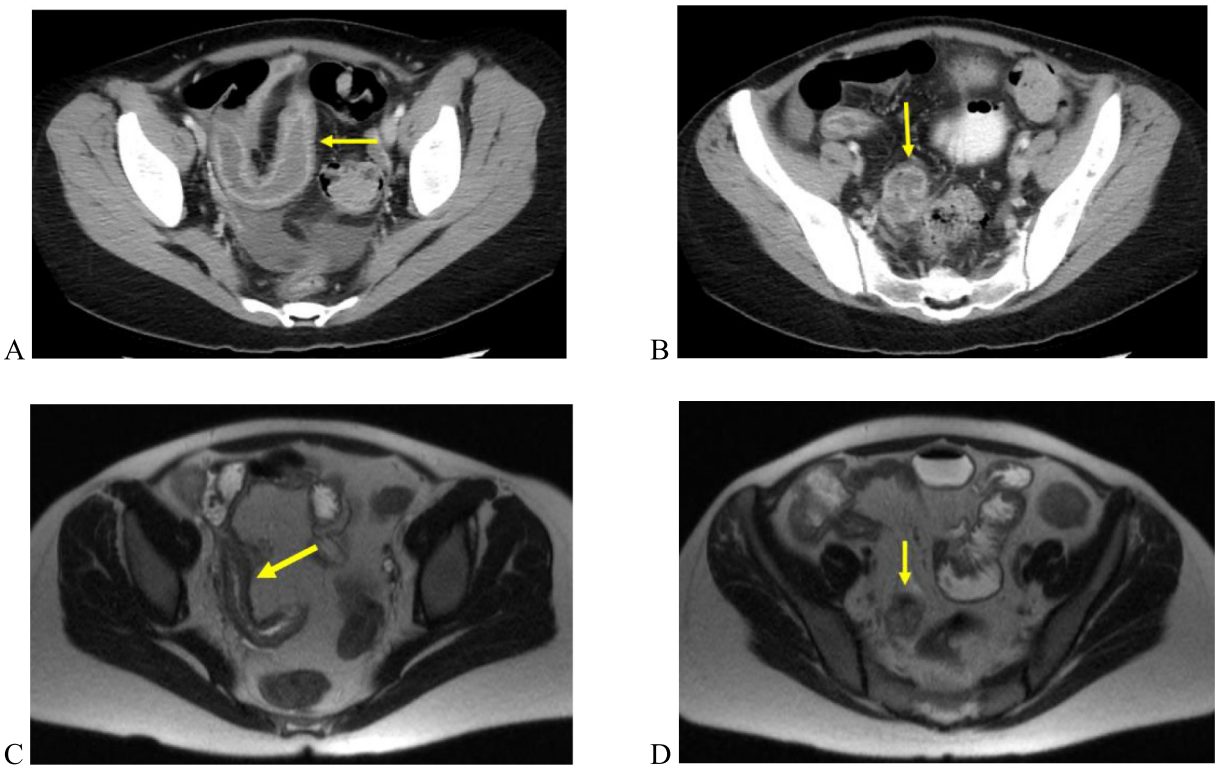


Fig. 3. 24 year old female with history of Crohn's disease, presenting with abdominal pain, rigid abdomen and vomiting. MRE performed 5 days after CT shows similar findings. A. Axial contrast-enhanced CT image of the pelvis shows findings of terminal ileitis with bowel wall thickening, mucosal hyperenhancement and surrounding fat stranding (arrow). Free fluid is also present. B. Axial contrast-enhanced CT image shows a 3 cm rim-enhancing fluid collection in the mid pelvis, consistent with abscess (arrow). C and D. Axial T2-weighted MR images of the pelvis show similar findings of terminal ileitis (C) and abscess (D). No additional pathology was identified at MR.

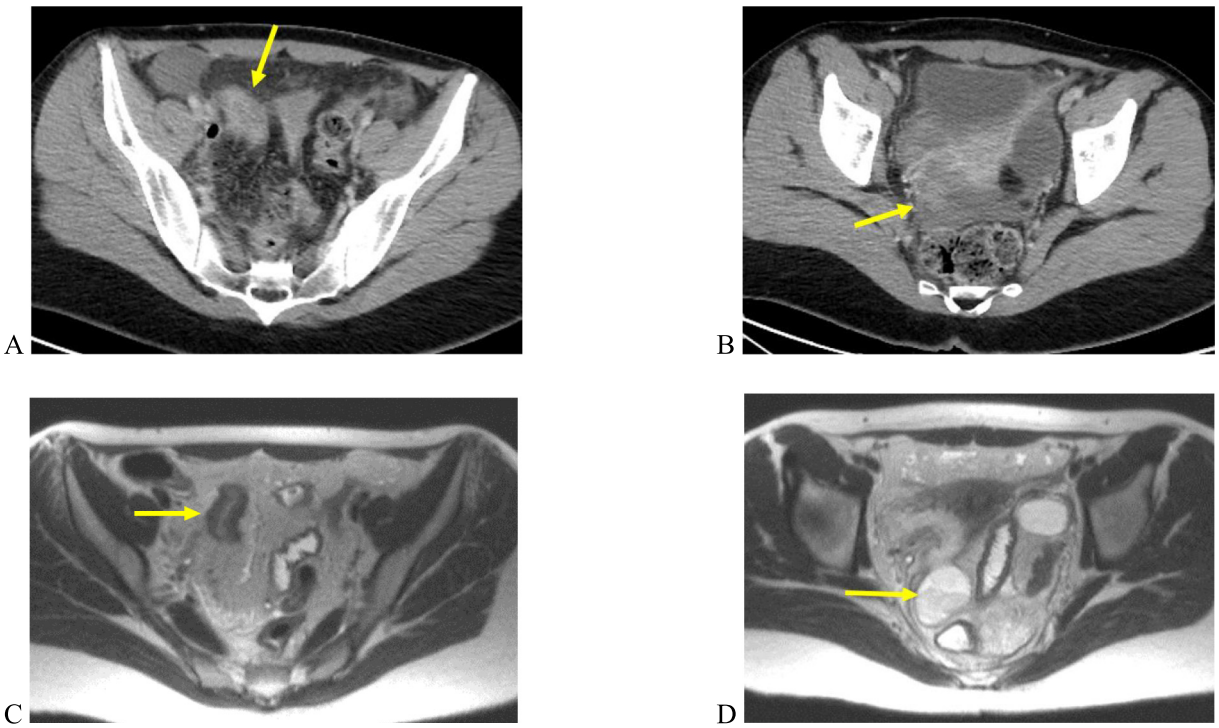


Fig. 4. 27 year old female with Crohn's disease presenting with abdominal pain and fever. A, B. Axial CT images through the pelvis show findings of terminal ileitis with wall thickening and fat stranding (A), as well as free fluid in the pelvis (B). No organized fluid collection is identified. C, D. Axial T2-weighted MR images (performed 7 days later) show similar findings of terminal ileitis (C). However, an abscess with a fluid level is now seen in the lower pelvis (D).

standard MR sequences, glucagon, and VoLumen. In addition, our short timeframe chosen between CT and subsequent MRE for each patient still leaves room for changes in the clinical status and corresponding imaging findings, particularly in a patient receiving appropriate medical treatment. As such, while findings on MRE were recognized with similar frequencies compared to the preceding CT, they may theoretically be missed or subclinical if a follow up CT was performed instead of MRE. Conversely, worsening clinical status (undetected during our screening process) may have resulted in new or more conspicuous imaging findings on follow up MRE. Lastly, although the subset of patients that met our strict inclusion criteria for this study was relatively small (45 out of 1000 total patients), it still corresponds to a significant number of potentially unnecessary MRE exams performed, naturally associated with their own risks, patient discomfort, and cost.

It has been recently observed that while the rate of imaging of inflammatory bowel disease patients appears to be increasing, there is no corresponding increase in identification of clinically actionable findings [19]. This is especially troublesome given cumulative dosages of radiation with repeated CT examinations. The objective should be to identify those patients who do not require urgent imaging but can be imaged with MRE electively [20] or perhaps be stratified into a low risk group using various emerging validation tools [21] and thus avoid unnecessary imaging altogether.

5. Conclusion

In conclusion, we found that the sensitivities of CT and MRE in detecting most relevant acute findings of Crohn's disease are not significantly different. The results of this study suggest the routine use of MRE shortly after a diagnostic CT should be avoided in patients who show no signs of clinical deterioration, as it provides no additional valuable information, at the expense of extra patient risks, discomfort, and higher health care costs. If eventual follow up is desired for routine surveillance then MRE clearly represents a viable option that spares radiation for this young patient population.

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