



Is the Mixed Use of Magnetic Resonance Enterography and Computed Tomography Enterography Adequate for Routine Periodic Follow-Up of Bowel Inflammation in Patients with Crohn's Disease?

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Objective: Computed tomography enterography (CTE) and magnetic resonance enterography (MRE) are considered substitutes for each other for evaluating Crohn's disease (CD). However, the adequacy of mixing them for routine periodic follow-up for CD has not been established. This study aimed to compare MRE alone with the mixed use of CTE and MRE for the periodic follow-up of small bowel inflammation in patients with CD.

Materials and Methods: We retrospectively compared two non-randomized groups, each comprising 96 patients with CD. One group underwent CTE and MRE (MRE followed by CTE or vice versa) for the follow-up of CD (interval, 13–27 months [median, 22 months]), and the other group underwent MRE alone (interval, 15–26 months [median, 21 months]). However, these two groups were similar in clinical characteristics. Three independent readers from three different institutions determined whether inflammation had decreased, remained unchanged, or increased within the entire small bowel and the terminal ileum based on sequential enterography of the patients after appropriate blinding. We compared the two groups for inter-reader agreement and accuracy (terminal ileum only) using endoscopy as the reference standard for enterographic interpretation.

Results: The inter-reader agreement was greater in the MRE alone group for the entire small bowel (intraclass correlation coefficient [ICC]: 0.683 vs. 0.473; $p = 0.005$) and the terminal ileum (ICC: 0.656 vs. 0.490; $p = 0.030$). The interpretation accuracy was higher in the MRE alone group without statistical significance (70.9%–74.5% vs. 57.9%–64.9% in individual readers; adjusted odds ratio = 3.21; $p = 0.077$).

Conclusion: The mixed use of CTE and MRE was inferior to MRE alone in terms of inter-reader reliability and could probably be less accurate than MRE alone for routine monitoring of small bowel inflammation in patients with CD. Therefore, the consistent use of MRE is favored for this purpose.

Keywords: Crohn's disease; MR enterography; CT enterography; Activity; Monitoring

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INTRODUCTION

Since the introduction of disease-modifying therapy for Crohn's disease (CD), including biologic agents and immunosuppressive treatment, the goal for the treatment of CD has changed from symptomatic control to disease remission [1]. Consequently, periodic monitoring of the disease, regardless of patient symptoms after the administration of medications, has become crucial for managing patients with CD. For small bowel follow-up, radiological imaging plays a vital role, as the small bowel is more challenging to evaluate with endoscopy than the colorectum [2,3]. Both magnetic resonance enterography (MRE) and computed tomography enterography (CTE) are considered appropriate for the therapeutic monitoring of CD according to current practice guidelines [4]. Although MRE is preferred owing to the lack of radiation exposure, it is more costly and generally less readily accessible than CTE [2,5]. Therefore, CTE is often used as an alternative to MRE in clinical practice for the management of patients with CD. MRE and CTE are often cited to have similar performances in evaluating CD, which is another reason they are generally considered as substitutes for each other. However, the similar performances of MRE and CTE, as reported in multiple studies, is only in terms of diagnosing the active inflammation of CD at a single time point [6,7]. Multiple studies have investigated the use of MRE alone or CTE alone as a tool for the therapeutic monitoring of CD [8-16]. However, to the best of our knowledge, there are no explicit comparative results to show whether MRE and CTE have similar performances for assessing changes in CD-related inflammation through follow-up. Furthermore, no data exist on whether combining the two modalities or using a single modality for the follow-up of CD results in the same assessment of interval change in bowel inflammation. It is unknown whether the mixed use of CTE and MRE for follow-up may introduce irregularities, given the physical and technical differences between the two imaging methods. This knowledge would guide the appropriate use of radiological enterography examinations for monitoring CD. Therefore, this study aimed to compare MRE alone with the mixed use of CTE and MRE for reliability and accuracy in assessing changes in small bowel inflammation during the routine periodic follow-up of patients with CD.

MATERIALS AND METHODS

Ethical Considerations

This retrospective study was approved by the Institutional Review Board of Asan Medical Center (IRB No. 2020-0110). The requirement for informed patient consent was waived.

Study Population

A two-step process was used to select the study population from patients with CD who were managed at the inflammatory bowel disease (IBD) center of Asan Medical Center, a tertiary referral hospital. First, the patients who fulfilled the following initial eligibility criteria were identified from the IBD registry of the center, which had been prospectively maintained and updated since 1997, as described elsewhere [17]: 1) diagnosis of CD, 2) MRE examination performed between July 2016 and June 2017 (referred to as "anchor MRE" hereinafter), 3) age of ≥ 18 years at the time of the anchor MRE examination, 4) CTE or MRE performed before or after the anchor MRE for routine interval follow-up of CD, and 5) medical management alone without bowel surgery within the period between the anchor MRE and before or after enterography. There were 258 eligible patients, of whom 204 had undergone CTE ($n = 133$) or MRE ($n = 71$) before the anchor MRE and 209 patients had undergone CTE ($n = 48$) and MRE ($n = 161$) after the anchor MRE, as shown in Figure 1. In our practice during the study period, patients with CD were routinely followed up using CTE or MRE typically every other year or every year, and the choice of CTE or MRE and the timing of the examinations were determined based on scheduling availability (i.e., waiting list), the preference of individual practitioners, and the status and preference of patients; the use of MRE has been increasing more recently.

Of those identified during the first step, we drew two groups of the same size: the "mixed CTE-MRE" group comprising patients who had been followed up using CTE and MRE and the "MRE alone" group comprising patients who had been followed up using MRE alone, as shown in Figure 1. For the mixed CTE-MRE group, we included the same number of patients who underwent CTE before and after the anchor MRE to prevent bias during image interpretation. Since 48 patients underwent CTE after the anchor MRE, the same number of patients were chosen from the patients who underwent CTE before the anchor MRE. Twenty-five of the 133 patients who underwent CTE before the anchor MRE also belonged to the 48 patients who

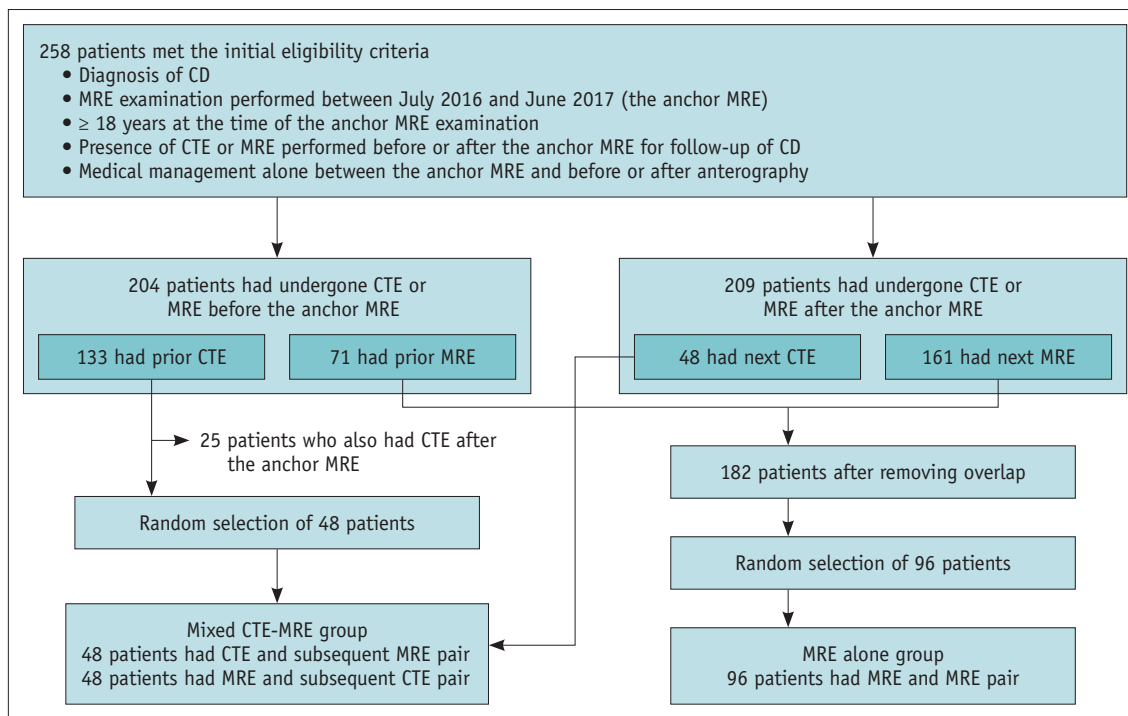


Fig. 1. Patient selection process. CD = Crohn's disease, CTE = computed tomography enterography, MRE = magnetic resonance enterography

underwent CTE after anchor MRE. These 25 patients were removed first to avoid selecting any of them twice. Forty-eight patients were randomly selected from the remaining 108 patients. Therefore, the mixed CTE-MRE group included 96 patients. Subsequently, we randomly chose 96 patients from 182 patients who had been evaluated with MRE alone (i.e., 71 patients + 161 patients - 50 patients who had undergone MRE both before and after the anchor MRE). The final study population comprised two groups of patients (Table 1). All the patients in each group were different. However, there was an overlap of 21 patients between the two groups.

CTE and MRE Acquisition

All CTE and MRE examinations were performed at a single institution and after oral administration of 1200 mL of polyethylene glycol to achieve fluid distention of the bowel. For CTE, enteric-phase images were obtained after intravenous bolus administration of a non-ionic iodinated contrast (100–150 mL of 320 mgI/mL) at a rate of 3 mL/s using 32- to 128-detector row scanners (SOMATOM series; Siemens). The scan parameters were as follows: beam pitch, 1; gantry rotation time, 0.5 seconds; field of view to fit; 100 or 120 kVp; and automated tube current modulation (CARE Dose 4D) with quality reference mAs set at 200. Both axial and coronal images were obtained with a 3-mm

thickness at 3-mm intervals. For MRE, T2-weighted images with and without fat suppression, diffusion-weighted images (with b factors of 0 and 900 sec/mm²), and T1-weighted images with fat suppression before and after intravenous administration of gadolinium contrast were obtained using a 3T scanner (Ingenua; Philips Healthcare). For contrast enhancement, 0.2 mL/kg of gadoterate meglumine (Dotarem; Guerbet) was intravenously administered at a rate of 2 mL/s, followed by a saline flush. To avoid bowel peristalsis, 20 mg of scopolamine-N-butyl bromide (Buscopan; Boehringer Ingelheim) was administered intravenously. Further technical details are provided in Supplementary Table 1 and can be found elsewhere [18,19].

CTE and MRE Interpretation

The 192 pairs of enterography examinations (i.e., 96 patients in each group) were anonymized, organized into batches of 10 examination pairs, and uploaded to an independent central reading system (AiCRO; Asan Image Metrics at <https://aim-aicro.com/>) for analysis. Each batch included five patients each from the mixed CTE-MRE and MRE alone groups, except for the last batch that had six patients from each group. The readers were instructed to review one batch per day. We divided the entire dataset into batches to allow the image review to proceed

Table 1. Characteristics of Study Patients

Characteristic	Mixed CTE-MRE Group (n = 96)	MRE Alone Group (n = 96)	P
Age at diagnosis of CD, year	23 (18–27)	24 (17–30)	0.976
Sex			0.365
Male	74 (77.1)	80 (83.3)	
Female	22 (22.9)	16 (16.7)	
Current smoker at diagnosis of CD			0.734
No	75 (78.1)	72 (75.0)	
Yes	21 (21.9)	24 (25.0)	
History of bowel surgery before the 1st CTE/MRE			0.764
No	63 (65.6)	60 (62.5)	
Yes	33 (34.4)	36 (37.5)	
Age at the time of 1st CTE/MRE, year	28 (21–33)	28 (21–36)	0.971
Disease location by Montreal classification at the time of the 1st CTE/MRE			0.497
L1 (ileum)	20 (20.8)	25 (26.0)	
L2 (colon)	4 (4.2)	1 (1.0)	
L3 (ileocolon)	71 (74.0)	69 (71.9)	
Unavailable	1 (1.0)	1 (1.0)	
Disease behavior by Montreal classification at the time of the 1st CTE/MRE			0.758
B1 (non-stricturing, non-penetrating)	47 (49.0)	46 (47.9)	
B2 (stricturing)	11 (11.5)	13 (13.5)	
B3 (penetrating)	37 (38.5)	37 (38.5)	
Unavailable	1 (1.0)	0 (0.0)	
CDAI score category at the time of the 1st CTE/MRE			0.262
< 150	72 (75.0)	75 (78.1)	
150–219	9 (9.4)	14 (14.6)	
220–450	7 (7.3)	2 (2.1)	
> 450	1 (1.0)	0 (0.0)	
Unavailable	7 (7.3)	5 (5.2)	
CRP at the time of the 1st CTE/MRE, mg/dL	0.35 (0.12–1.2)	0.19 (0.1–0.62)	0.012
Fecal calprotectin at the time of the 1st CTE/MRE			0.764
Value in available patients, mg/kg	479 (79.1–970)	315 (69.9–1108.3)	
Unavailable	57 (59.4)	42 (43.8)	
Interval between the 1st and 2nd CTE/MRE, month	22 (13–27)	21 (15–26)	0.348
Medication between the 1st and 2nd CTE/MRE*			0.823
Aminosalicylate	52 (54.2)	46 (47.9)	
Corticosteroid	9 (9.4)	5 (5.2)	
Thiopurine	71 (74.0)	81 (84.4)	
Methotrexate	3 (3.1)	4 (4.2)	
Anti-TNF	45 (46.9)	49 (51.0)	
Vedolizumab or risankizumab	1 (1.0)	2 (2.1)	
No IBD medication	3 (3.1)	2 (2.1)	
Age at the time of 2nd CTE/MRE, year	30 (24–35)	30 (23–38)	0.959
CDAI score category at the time of the 2nd CTE/MRE			0.217
< 150	83 (86.5)	85 (88.5)	
150–219	4 (4.2)	8 (8.3)	
220–450	4 (4.2)	1 (1.0)	
> 450	0 (0.0)	0 (0.0)	
Unavailable	5 (5.2)	2 (2.1)	
CRP at the time of the 2nd CTE/MRE, mg/dL	0.14 (0.1–0.52)	0.17 (0.1–0.73)	0.600

Table 1. Characteristics of Study Patients (Continued)

Characteristic	Mixed CTE-MRE Group (n = 96)	MRE Alone Group (n = 96)	P
Fecal calprotectin at the time of the 2nd CTE/MRE			
Value in available patients, mg/kg	194 (53.3–719)	206.5 (59.5–558)	0.737
Unavailable	37 (38.5)	40 (41.7)	
Endoscopic reference standard for the terminal ileum (interval change of CD inflammation)			
Decreased	20 (20.8)	13 (13.5)	0.537
Unchanged	28 (29.2)	34 (35.4)	
Increased	9 (9.4)	8 (8.3)	
Unavailable	39 (40.6)	41 (42.7)	

Continuous variables were expressed as median (interquartile range). Categorical variables were expressed as number (percentage). *The sum is greater than 96 patients and 100% as some patients received multiple different medications. CD = Crohn's disease, CDAI = Crohn's disease activity index, CRP = C-reactive protein, CTE = computed tomography enterography, IBD = inflammatory bowel disease, MRE = magnetic resonance enterography, TNF = tumor necrosis factor

uniformly for both groups and to be similar to that in real-world practice by preventing the cramming of too many cases within a single reading session. Considering that 21 patients were included in both groups, we allowed any particular patient to be included in a batch only once to prevent bias during image interpretation. Otherwise, the selection of five patients from each group was random. Three board-certified gastrointestinal radiologists from three different institutions, all of whom had a similar experience with CTE and MRE evaluation of CD (each with 2 to 3 years of experience, including a minimum of 200-case experience separately for CTE and MRE), independently performed image interpretation. The readers were blinded to all clinical information, except for the diagnosis of CD. They qualitatively determined whether the CD-related inflammation had decreased, not changed, or increased within the period between the two sequential examinations for the entire small bowel and separately for the terminal ileum (or neo-terminal ileum in patients post-surgery), defined as the most distal 10 cm of the small bowel. As CD often involves multiple bowel areas, all areas of bowel inflammation in the target bowel regions were considered together. The collective interpretation for a patient was made as follows: 1) decreased = decrease in the overall extent of bowel inflammation or the severity of inflammation in any location of bowel inflammation; 2) no change = no change in the extent and severity of bowel inflammation; and 3) increased = increase in the overall extent of bowel inflammation or the severity of inflammation in any location of bowel inflammation. The assessment of bowel inflammation on enterography followed recent expert consensus recommendations [20]. For the MRE-to-MRE comparison, changes in the mural and

perienteric signals on T2-weighted images, mural thickness, mural hyperenhancement, mural diffusion restriction, and individual ulcers (if visible) were evaluated (Fig. 2) [2,20]. For the CTE-to-MRE comparison, some of the aforementioned features were not applicable. Therefore, the readers considered the changes in mural thickness and individual ulcers (if visible) and referred to indirect findings (Fig. 3). We could not use any (semi-) quantitative scoring or measurements to assess bowel inflammation, as no such methods could be applied universally to MRE and CTE.

Clinical Data Collection

Various patient- and disease-related data were obtained from the center's IBD registry mentioned earlier and included demographic data, findings at the initial diagnosis of CD and at the times of the first and the second enterography examinations, the interval between the two enterography examinations, and the medications administered (Table 1). At the IBD center, the patients were routinely followed up at the outpatient clinic, typically at 2-month intervals, and CD activity index (CDAI) measurements and laboratory tests were performed. Endoscopy findings for the terminal ileum (or neo-terminal ileum in patients post-surgery), performed within \pm 3 months of the first and second enterography examinations, were also collected. We adopted the three-month limit in this study, as it was regarded as an acceptable interval for comparing endoscopic results with other data in retrospective research of CD, considering the chronic nature of the disease [21,22]. In our practice, endoscopic examinations were performed by board-certified gastroenterologists experienced in CD. The examiners recorded qualitative changes in bowel inflammation based on the findings of the prior examination, which included

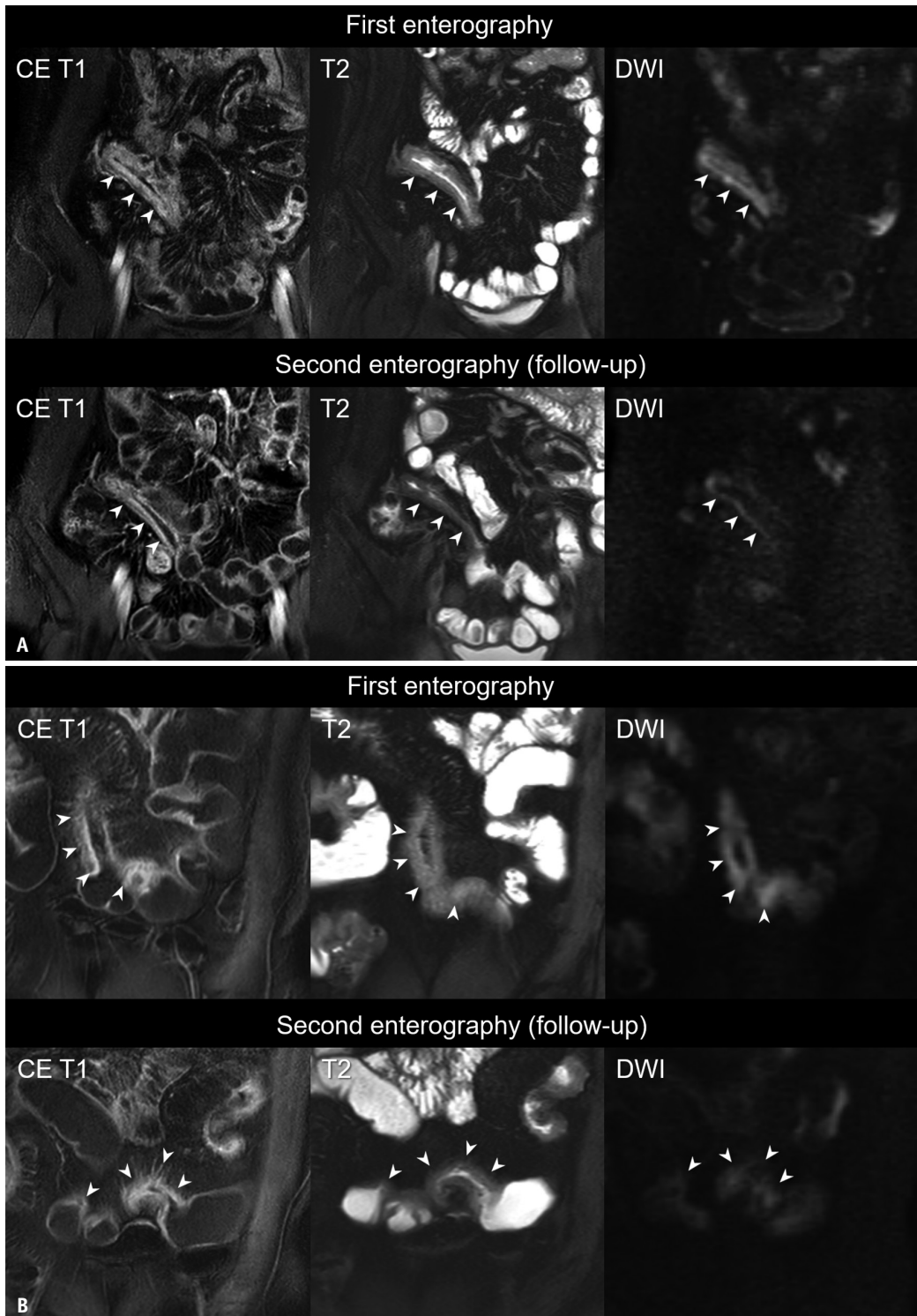


Fig. 2. Examples showing changes in CD inflammation in an MRE-to-MRE comparison.

A. All images are coronal. Decreased inflammation in the ileal segment labeled by arrowheads on the second MRE, compared with the first MRE, was noted in all three image sequences due to the decrease in mural thickening, the hypersignal on T2, and diffusion restriction on DWI. All three readers made a consistent interpretation of 'decreased' on follow-up MRE. **B.** All images are coronal. The ileal segment of interest labeled by arrowheads shows different configurations for two MRE examinations due to bowel mobility. Mural abnormalities in the ileal segment due to CD inflammation appear similar in CE T1 between the two studies. However, the mural hypersignal on T2 and diffusion restriction on DWI decreased between the two MRE examinations, indicating reduced inflammation. All three readers made a consistent interpretation of 'decreased' on follow-up MRE. A CTE-to-MRE comparison would likely fail to recognize the change. CD = Crohn's disease, CE T1 = contrast-enhanced T1-weighted image, DWI = diffusion-weighted image, MRE = magnetic resonance enterography, T2 = T2-weighted image



Fig. 3. Examples showing changes in CD inflammation in CTE-to-MRE comparison.

A. All images are coronal. The ileal segments of interest labeled by arrowheads are at slightly different locations for the two examinations due to bowel mobility. More severe inflammation in the ileal segments on CTE, compared with MRE, is well-appreciated by the greater mural thickness (preferentially involving the mesenteric border) and more prominent engorgement of the vasa recta. All three readers made a consistent interpretation of 'decreased' on the MRE. **B.** All images are coronal. More severe inflammation in the ileal segment labeled by arrowheads on MRE compared with CTE is recognized by the greater mural thickness (preferentially involving the mesenteric border) and the presence of a visible ulcer (U on MRE), which is not observed on CTE. All three readers made a consistent interpretation of 'increased' on the MRE. CD = Crohn's disease, CE T1 = contrast-enhanced T1-weighted image, CTE = computed tomography enterography, MRE = magnetic resonance enterography

the following: decreased/improved, increased/worsened, and unchanged. Scoring of bowel inflammation, such as using CD endoscopic index of severity (CDEIS) or simple endoscopic score for CD (SES-CD), was not available, as such scoring was mostly adopted for research purposes and was generally not used in our clinical practice.

Statistical Analysis

The patient characteristics of the two groups were compared using the Mann-Whitney U test, chi-squared test, Fisher's exact test, or Fisher-Freeman-Halton test, depending on the data type. The primary study outcome was the inter-reader agreement between the three readers in interpreting enterography follow-up using the three ordinal categories (decreased, unchanged, and increased). The degree of agreement was assessed using an intraclass correlation coefficient (ICC) estimated with a two-way random-effects model and an absolute agreement assumption, as recommended [23,24]. We compared the ICC values of the two groups using the z-test (Supplement). The analysis was performed for the entire small bowel and terminal ileum. As the secondary outcome from this study, the accuracy of the enterography follow-up was assessed for the terminal ileum using endoscopic findings as the reference standard. A complete agreement with the endoscopic findings was indicative of an accurate enterographic interpretation. We compared the accuracies of the two groups across the three readers using a multivariable logistic regression model, for which the parameters were estimated using generalized estimating equations (GEEs) with an unstructured

correlation structure. GEEs were used to account for the repeated data structure and the correlation between the three readers. The regression model included the group as the main factor and the reader as a covariate. An adjusted odds ratio greater than 1 indicated a higher accuracy in the MRE alone group than in the CTE-MRE group (reference category). Statistical significance was set at $p < 0.05$.

RESULTS

Study Population

The characteristics of the patients included in this study are summarized in Table 1. The two groups did not have significantly different characteristics, except C-reactive protein (CRP) values at the time of the first enterography. The inter-group difference in CRP values was minimal and within a range without clinical significance.

Inter-Reader Agreement in Interpreting Enterography Follow-Up

The results of the comparison between the two groups are summarized in Table 2. The inter-reader agreement of the three readers in interpreting follow-up enterography using the three ordinal categories (decreased, unchanged, and increased) was significantly greater in the MRE alone group for the entire small bowel (ICC = 0.683 vs. 0.473; $p = 0.005$) and the terminal ileum (ICC of 0.656 vs. 0.490; $p = 0.030$). The results of the comparison were essentially consistent across the subsets of patients who underwent CTE followed by MRE or MRE followed by CTE in the mixed CTE-MRE

Table 2. Inter-Reader Agreement for Interpretation of Follow-Up Enterography

	ICC (95% CI)		P*
	Mixed CTE-MRE Group (n = 96)	MRE Alone Group (n = 96)	
Entire small bowel			
All patients	0.473 (0.350, 0.590)	0.683 (0.590, 0.764)	0.005
Patients with CTE followed by MRE (n = 48)	0.456 (0.284, 0.620)		0.016
Patients with MRE followed by CTE (n = 48)	0.494 (0.303, 0.661)		0.040
Terminal ileum			
All patients	0.490 (0.370, 0.604)	0.656 (0.558, 0.742)	0.030
Patients with CTE followed by MRE (n = 48)	0.530 (0.365, 0.679)		0.170
Patients with MRE followed by CTE (n = 48)	0.449 (0.275, 0.615)		0.032

*Comparison of the two groups. CI = confidence interval, CTE = computed tomography enterography, ICC = intraclass correlation coefficient, MRE = magnetic resonance enterography

Table 3. Accuracy of Enterography Follow-Up

	Mixed CTE-MRE Group (n = 57)	MRE Alone Group (n = 55)	P*
All readers	62.6 (107/171)	72.7 (120/165)	0.077
Reader 1	64.9 (37/57)	74.5 (41/55)	
Reader 2	57.9 (33/57)	72.7 (40/55)	
Reader 3	64.9 (37/57)	70.9 (39/55)	

Data are presented as % with the patient number in the parentheses. *Comparison of the two groups across all three readers using a multivariable logistic regression model for which the parameters were estimated using generalized estimating equations to account for the repeated data structure and correlation between the three readers. CTE = computed tomography enterography, MRE = magnetic resonance enterography

group. The complete cross-tabulation of the interpretation of the three readers is provided in Supplementary Figs. 1, 2. For the entire small bowel, of the 288 inter-reader pairs of interpretations among the three readers for each group (i.e., 96 patients x 3 reader combinations), there were 98 and two instances of disagreements for one category and two categories (i.e., opposing interpretations), respectively, in the mixed CTE-MRE group, whereas all 62 instances of disagreement were for one category in the MRE alone group (Supplementary Fig. 1). For the terminal ileum, all 82 instances of disagreement in the mixed CTE-MRE group and all 50 instances in the MRE alone group were for one category (Supplementary Fig. 2).

Accuracy of Enterography Follow-Up

Endoscopic reference standard information for the terminal ileum was available for 57 (59.4%) and 55 (57.3%) patients in the mixed CTE-MRE and MRE alone groups, respectively. The rates were not significantly different ($p = 0.884$). In patients who had an endoscopic reference standard, the median interval between endoscopy and

enterography was 6 days (interquartile range, 2–18 days) and 5 days (interquartile range, 3–13 days) for the mixed CTE-MRE and MRE alone groups, respectively. The accuracy of enterography for diagnosing decreased, unchanged, and increased inflammation in the terminal ileum is summarized in Table 3. The accuracy for the MRE alone group was higher than that for the mixed CTE-MRE group without statistical significance, with the adjusted odds ratio of 3.21 (95% confidence interval, 0.88–11.69) ($p = 0.077$). The accuracy of the individual readers ranged from 70.9% to 74.5% for the MRE alone group and from 57.9% to 64.9% for the mixed CTE-MRE group. The cross-tabulation of the enterographic interpretations against the endoscopic reference standard is provided in Table 4. The entire output of the statistical analysis using a multivariable logistic regression model and GEE is provided in Supplementary Table 2.

DISCUSSION

Our study indicated that the mixed use of CTE and MRE was probably not the best strategy for routine periodic monitoring of disease activity in the small bowel in patients with CD. The combination of CTE and MRE showed inferior test characteristics to those of MRE alone, including lower inter-reader reliability and lower accuracy (albeit without statistical significance), in assessing the interval change for CD inflammation between the two follow-up time points. High reliability and accuracy are important characteristics that a good diagnostic strategy requires. Reliability is particularly important for a diagnostic approach that is widely accepted in real-world clinical practice.

The superior performance of MRE alone for monitoring is likely due to several factors. MRE provides more imaging

Table 4. Cross-Tabulation of Enterography Interpretations Against the Endoscopic Reference Standard for the Terminal Ileum

	Reader 1			Reader 2			Reader 3		
	Decreased	Unchanged	Increased	Decreased	Unchanged	Increased	Decreased	Unchanged	Increased
Mixed CTE-MRE Group (n = 57)									
Endoscopy									
Decreased	11	8	1	7	13	0	9	11	0
Unchanged	5	23	0	2	25	1	1	27	0
Increased	1	5	3	0	8	1	0	8	1
MRE alone group (n = 55)									
Endoscopy									
Decreased	9	4	0	7	6	0	4	9	0
Unchanged	3	29	2	2	30	2	1	33	0
Increased	0	5	3	0	5	3	0	6	2

CTE = computed tomography enterography, MRE = magnetic resonance enterography

features for assessing bowel inflammation, including data that cannot be obtained with CTE, such as signal intensity on T2-weighted images and diffusion restriction [20,25]. The interpretation would become more straightforward, confident, and consistent by referring to the changes in multiple imaging features. Furthermore, it is difficult to compare the degree of mural hyperenhancement, one of the cardinal signs of active bowel inflammation in CD, detected by CTE and MRE, because their technical mechanisms of contrast enhancement and tissue contrast are different and the degree of mural enhancement may not be an accurate indicator of inflammatory severity unless some internal normalization or quantitative measures are utilized [2,20]. Therefore, the comparison of CTE and MRE is mostly reduced to observe an apparent decrease or increase in the extent of bowel inflammation and changes in mural thickness.

It should be noted that the study results would only apply to routine periodic monitoring of bowel inflammation in patients with CD who have been relatively stabilized (in this study, approximately 3/4 of the patients included had a CDAI of < 150 at the time of the anchor MRE). In some other clinical settings, such as if the patient is acutely ill or presents with unexpected symptoms or findings suggestive of complications, CTE, or non-enterographic abdominopelvic CT, is favored [2,5]. Our results do not apply to such settings, and the preferred use of MRE should not be extended to such clinical scenarios. In addition, our results may not be generalizable to patients who undergo enterography as part of the initial follow-up after the administration of disease-modifying therapy or a medication change, and patients in clinical trials, as the patients in these scenarios frequently have more severe baseline inflammation and a shorter follow-up interval [1,26,27].

For routine periodic monitoring of bowel inflammation in patients with CD, the consistent use of MRE can provide other benefits in addition to superior performance characteristics. The lack of radiation exposure is a clear advantage of MRE in this setting, particularly given the regular repetitive nature of the evaluation. Although current computed tomography techniques allow for a remarkable reduction in the radiation dose for CTE, radiation exposure associated with CTE in patients with CD remains a concern [28-34]. We did not address the use of CTE alone in our study, as we judged that this strategy may not be as widely adopted as the use of MRE alone or mixed CTE and MRE, considering the amount of radiation exposure. For the same reason, routine periodic follow-up of patients with CD using CTE alone has become unusual in our practice. In addition, MRE has an advantage over CTE in drawing (semi-) quantitative indices of bowel inflammatory activity. Multiple scoring systems for assessing CD activity on MRE are already available, such as the magnetic resonance index of activity (MaRIA), simplified MaRIA, CD magnetic resonance imaging index, and Nancy score, even though they are not yet widely used in clinical practice [35-38]. Our research makes another case for the preferred use of MRE beyond these known factors and specifically helps prevent unwittingly combining CTE and MRE for the periodic monitoring of CD activity. The costlier and generally less readily accessible nature of MRE compared with CTE remains a practical hurdle.

This study has some limitations. First, this was a retrospective and nonrandomized study. The two groups in our study had various similar characteristics, which may have helped emphasize the lack of substantial biases. Nevertheless, a prospective, randomized comparison would provide even more definite results. Second, the retrospective

use of the clinical endoscopic findings as the reference standard for analyzing the accuracy of enterography follow-up had limitations. This reduced the sample size and statistical power of the study as patients whose endoscopic results were not available were excluded. As endoscopic terminal ileal evaluation lengths often vary across patients in clinical practice, there could be some inaccuracies due to minor locational mismatches between enterography interpretations and endoscopic findings. However, we suspect that such inaccuracies would have affected the two groups similarly. In addition, the use of formal scoring for endoscopic inflammatory activity, such as CDEIS or SES-CD, would have made the analysis more precise and informative. Third, our study focused on the reliability of interpretation, although the reliability of the entire enterography examination is also affected by technical reliability. It is generally more difficult to maintain the technical reliability of magnetic resonance imaging than computed tomography.

In conclusion, the mixed use of CTE and MRE was inferior to MRE alone in terms of inter-reader reliability and could probably be less accurate for routine periodic monitoring of bowel inflammatory activity in patients with CD. Therefore, the consistent use of MRE is favored for this purpose, and the mixed use of CTE and MRE is probably not the best strategy. Despite some related guidelines [1,26,27], the use of enterography in post-therapy follow-up is yet to be standardized. Our study may help establish such guidelines.

Supplement

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Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Seong Ho Park, Sang Hyoung Park. Formal analysis: Seong Ho Park, Sang Hyun Choi. Funding acquisition: Seong Ho Park. Investigation: Jiyeon Ha, Jung Hee Son, Ji Hun Kang, Byong Duk Ye, So Hyun Park, Bohyun Kim, Sang Hyoung Park, Suk-Kyun Yang. Methodology: Jiyeon Ha, Seong Ho Park. Project administration: Seong Ho Park. Resources: all authors. Supervision: Seong Ho Park, Byong Duk Ye, Suk-Kyun Yang. Writing—original draft: Jiyeon Ha. Writing—review & editing: Seong Ho Park, Jung

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