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The role of magnetic resonance enterography and diffusion-weighted imaging in pediatric inflammatory bowel disease compared to endoscopic and clinical activity scores: pilot study

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Abstract

Background Inflammatory bowel disease (IBD) is considered as significant cause of morbidity in children with a global rise in its pediatric onset recently. Our study aimed to assess the facility of magnetic resonance enterography (MRE) and diffusion-weighted imaging (DWI) to identify the activity of pediatric IBD in correlation with clinical and endoscopic activity scores. Twenty-four patients of IBD who underwent clinical examination, ileocolonoscopy and MRE and DWI within less than 14 days were prospectively included. For all Crohn's cases (9/24), the simplified endoscopic activity score for Crohn's disease (SES-CD) and magnetic resonance enterography global score (MEGS) were acquired, while for all UC (15/24) cases, MRE score and Mayo endoscopic score were calculated. Sensitivity and specificity of MRE for detection disease activity against clinical and endoscopic scores were compared. Pathological reference for disease activity was based on assessment for mucosal inflammatory changes on endoscopic biopsy in all cases.

Results There was a perfect inter-observer agreement (kappa 0.81–1) regarding wall thickening and mural edema, with substantial agreement (kappa 0.61–0.8) for MRE severity score, mural diffusion restriction, mesenteric edema and vascular congestion, while mural enhancement and for number of active LNs revealed moderate agreement (kappa 0.41–0.6). There was a significant positive correlation between MEGS and SES-CD in Crohn's cases as well as between Mayo endoscopic score and MRE severity in UC cases ($r=0.970$, $p>0.001$ and $r=0.544$, $p=0.036$, respectively). MRE compared to endoscopic findings and clinical activity scores revealed high accuracy (95.8%) with 87.5%, 80%, 96% and 94.1% for sensitivity, specificity, PPV and NPV, respectively.

Conclusion MR enterography is a noninvasive reliable imaging modality of high accuracy for the diagnosis of pediatric IBD severity compared to endoscopic activity scores and pathological severity.

Keywords Magnetic resonance enterography, Diffusion MR, Endoscopy, Crohn's disease, Ulcerative colitis

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Background

Inflammatory bowel diseases (IBD) include range of conditions generally grouped into ulcerative colitis (UC), Crohn's disease (CD) and IBD-unclassified (IBD-U) constructed on clinical, laboratory, radiological, endoscopic and histological standards [1]. CD and UC are immunologically mediated chronic inflammatory diseases and considered as significant cause of morbidity in children with a global rise in their pediatric onset recently [2, 3].

CD is a chronic inflammatory transmural disorder which can affect any region of the gastrointestinal tract in a discontinuous distribution [4]. While UC affects the mucosa and submucosa in continuous manner and limited to the colon, it frequently starts in the rectum [5].

Accurate assessment of the extent of pediatric IBD is crucial to detect the ideal treatment strategies, mostly depending on endoscopy which is an invasive procedure with poor patient compliance [2]. MR enterography (MRE) is extensively used to evaluate disease activity, penetrating complications, surgical planning and follow-up [6].

Pediatric MRE is the imaging gold standard for IBD assessment and preferable over CT enterography owing to its excellent resolution and absence of ionizing radiation exposure [7, 8]. MR enterography-based scores have high accuracy for evaluating CD luminal activity, but till now no available CT enterography-based authorized scores for grading activity [9]. Also MRE can detect transmural disease not amenable to endoscopic assessment [10].

Multiple MRE scores were developed to assess CD activity, but magnetic resonance enterography global score (MEGS) allows better imitate of the disease activity as it includes the extra-enteric manifestations and the longitudinal disease extent [2, 11, 12].

Diffusion-weighted imaging (DWI) is a fast functional MR technique with wide acceptance in imaging of IBD as it depends on molecular motion and can illustrate inflammatory lesions in IBD [13, 14] also, DWI is fit for children, owing to quicker image acquisition [15].

With recent concerns around the accumulation of gadolinium in the brain after MRI scans, few studies have discussed the efficacy of DWI to substitute contrast-enhanced MRE for identifying the activity of IBD [15, 16].

To the best of our knowledge, no studies have precisely compared the diagnostic accuracy and inter-observer agreement of both MRE and DWI in detecting activity of pediatric IBD against endoscopic and clinical activity scores with pathological reference standard.

We aimed to estimate the capability of MRE to categorize the activity of pediatric IBD in correlation with

clinical, endoscopic and pathological activity score as reference standard and to assess the utility of DWI for the recognition of inflammation.

Methods

Patients

The institutional review board has approved the study and informed consent was obtained from all patients. We included IBD children aged less than 18 years old with clinically suspected relapse and cases with recently diagnosed IBD. All patients underwent clinical examination, ilio-colonoscopy with biopsies and histopathological results (reference standard), contrast-enhanced MR enterography and diffusion-weighted imaging with an interval of 2 weeks or less. No treatment specific IBD was given between the examinations. We excluded 16 patients from the study, six children were diagnosed as nonspecific colitis, two patients had no available endoscopic data, five patients had >2 weeks interval between MRE and ileocolonoscopy, and the last three patients were excluded due to image quality degradation (especially in DWI) caused by bowel peristalsis or large amount colonic gas. Lastly, 24 patients [11 boys and 13 girls] with pathologically proved UC (15/24) and CD (9/24) were prospectively included in the study in the period from April 2021 to May 2022. The flowchart of the study is illustrated in (Fig. 1).

Clinical, endoscopic and histological assessment

The clinical severity was evaluated employing Pediatric Ulcerative Colitis Activity Index parameters (PUCAI) as well as Pediatric Crohn's Disease Activity Index parameters in UC and CD patients, respectively. Ileocolonoscopy was performed to assess disease activity within less than 14 days from MRE and DWI. The endoscopic findings of 24 patients were scored by expert gastroenterologist using Simple Endoscopic Score for Crohn's disease (SES-CD) and the Mayo endoscopic score of ulcerative colitis to assess the severity [17, 18]. Mayo Endoscopic Score of (0) showed inactive UC, (1) mild UC in the form of mild friability or erythema, (2) moderate UC comprised severe erythema, friability with erosive areas and (3) severe UC involved spontaneous hemorrhage and ulcerations [17]. The SES-CD of (0–2) indicted inactive disease, (3–9) mild activity, (9–12) moderate or (≥ 12) severe activity [18].

Specialist pathologist evaluated the severity of the disease on endoscopic biopsy using Geboes scoring system for assessing UC and Scoring system for histological assessment of CD.

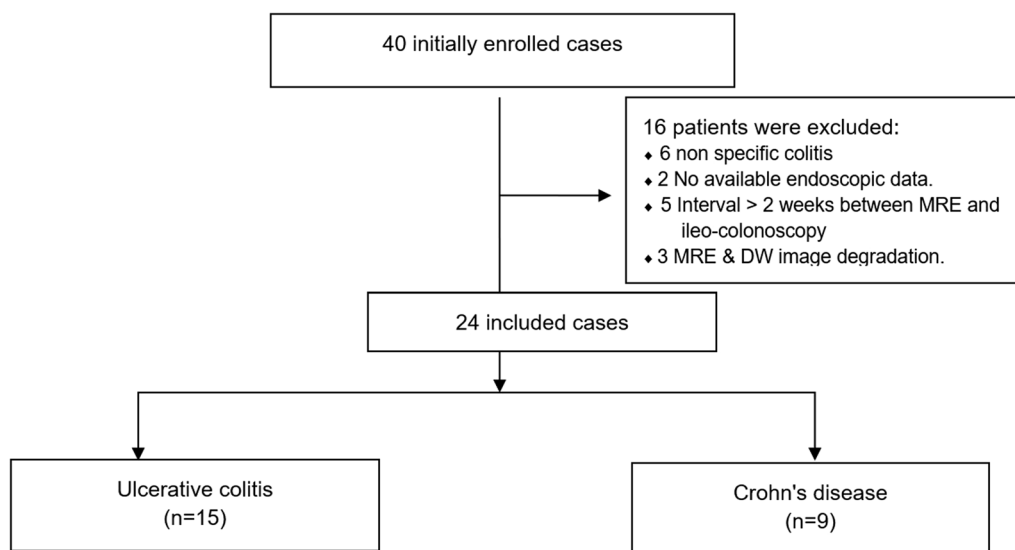


Fig. 1 Flowchart of the study

MRE technique

Patient preparation

All children had MRI at 1.5-T [Ingenia[®], Philips Healthcare]. Children fasted 4–6 h prior to MRI examination then followed by ingestion of a hyperosmolar oral contrast agent (water mixed with Mannitol 20%) for proper small bowel distension.

MRE

Children were examined in supine position with phased-array body coils. Pre-contrast MRI sequences included T1-weighted imaging (T1-WI) and FSE (fast spin echo) T2-WI with fat suppression. Also, half-Fourier single-shot turbo spin-echo (HASTE) and TRUFI (true free-induction steady-state-free precession) sequences were obtained in coronal and axial planes with the following parameters: slice thickness 4 mm; shortest TE/TR; FOV 350–450; matrix 256 × 256; flip angle 50°. Coronal and axial fat saturated 3D VIBE (volumetric interpolated breath-hold examination) T1 gradient-echo sequence were acquired before and after injection of contrast agent, gadolinium diethylene-triamine penta acetic acid (Gd-DTPA) at a dose of 0.5 mmol/kg using an automated MR injector.

DWI

DWI was obtained before contrast injection consuming fat-suppressed single-shot echoplanar sequence with b values ($b = 100, 600$ and 800 s/mm²). The following acquisition parameters were utilized; slice thickness

5 mm, slice gap 1 mm; TE = 70 ms, number of excitations (NEX) 3 and matrix 124 × 120,

Image analysis

MRE

The MR images were interpreted by two radiologists (with 25- and 8-year experience) who were blinded to patients' clinical scores and endoscopic data. For easier detection of disease extent, the bowel loops were subdivided into eight regions: the jejunum, ileum, terminal ileum and ileocecal junction, ascending colon, transverse colon, descending colon, sigmoid colon and rectum. Independently, each reviewer analyzed the MRE images and reviewed the MRI findings [19];

- i- Bowel wall inflammation; wall thickening, qualitative evaluation of mural edema on T2-weighted fat-suppressed images; grade 1, 2 or 3 if it was similar to muscles, liver, spleen, respectively, qualitative evaluation of the mural enhancement on T1-weighted fat-suppressed images; grade 1, 2 or 3 if enhancement was similar to that of muscles, splenic parenchyma, aorta, respectively, length of the affected segment and stricture.
- ii- The penetrating disease features; sinus tracts, abscesses, mesenteric edema, engorged vasa recta (comb sign), perianal fistulas and number of active lymph nodes (LN); active if exceeded 5 mm with contrast enhancement.
- iii- The extra-enteric findings: sacroilitis, cholangitis and GB stone.

Guided by MEGS [2, 12, 20], each reviewer separately categorized CD patients into three subgroups; mild, moderate and severe activity with scores (score 6–7), (score 8–13) and (score 14–18), respectively.

To date, there is no validated MRE scoring system for UC, so guided by the recorded MRE and DWI data [21] and radiologists' judgment, each radiologist classified 15 UC patients into three subgroups; mild, moderate and severe activity.

DWI

Each reviewer independently assessed DWI and ADC images to exclude T2-shine through and confirm the restricted diffusion. High signal intensity at high b value with corresponding low ADC signal (true diffusion restriction) is considered as an active lesion of IBD.

The MRE and DWI findings were compared with the clinical, endoscopic scores and histopathological activity.

Statistical analysis

The statistical analysis of data was performed by using SPSS program (Statistical package for social science version 20). Qualitative data were illustrated using number and percent. Quantitative data were illustrated using median for nonparametric data and mean, standard deviation for parametric data. Significance of the obtained results was considered at the (0.05) level. In the weighted kappa statistic (*K*), 95% confidence interval (CI) with percentage agreement was done to assess the proportion of agreement for both reviewers for bowel wall inflammation, penetrating disease and extraintestinal findings as well as the MEGS. Kappa agreement was with kappa (0.01–0.20: Slight agreement, 0.21–0.40: Fair agreement, 0.41–0.60: Moderate agreement, 0.61–0.80: Substantial agreement and 0.81–0.99: Perfect agreement). The accuracy, sensitivity and specificity of the MRE scoring for each reviewer were calculated. The correlation between MRE severity, clinical and endoscopic activity scores was assessed by Spearman's rank estimation.

Results

Patients' characteristics and clinical manifestations

Twenty-four patients with pathologically proved UC (15/24) and CD (9/24) were prospectively included with mean age 13.27 ± 3.53 and 13.78 ± 3.67 years, respectively. For Crohn's, two-thirds (66.7%) were males and one-third (33.3%) were females with reversed relation in UC. There was no statistically significant difference between UC and CD concerning sex, age, period of disease and treatment. Clinico-epidemiologic features and disease presentation are illustrated in (Table 1).

Endoscopic findings

Mayo endoscopic score of ulcerative colitis, SES-CD and simplified score for CD are illustrated in (Tables 2, 3, 4). SES-CD revealed that the allocation of involved segments was mostly ileum (77.7%) and right-sided colon (44.4%). The simplified score for CD per highest segment involved revealed that the median score for size of ulcers, ulcerated surface, and affected surface were 1.1, 1.4 and 1.3, respectively, while the presence of narrowing was 0.89 and total score median was 6. Mild disease was detected in 33.3% of cases, whereas inactive disease, moderate and severe disease each correspond to 22.2% of cases.

Histopathological findings

The overall score of Geboes scoring system for assessing ulcerative colitis histological activity was mainly moderate disease in ten cases (66.7%), mild in four cases (26.7%) and severe disease in one case (6.7%). In CD cases, histopathologic severity was assessed according to pathologist decision as follows; no detected cases in remission (0.0%), whereas mild, moderate and severe disease each correspond to (33.3%) of cases.

MRE findings

There was almost perfect inter-observer agreement (kappa 0.81–1) concerning mural edema and wall thickening, substantial agreement (kappa 0.61–0.8) for MRE severity score, mesenteric edema, mural diffusion restriction, and disease extent and moderate agreement (kappa 0.41–0.6) for mural enhancement (Table 5).

Statistically significant difference was revealed among UC and CD regarding mural edema (higher values were observed in moderate UC). There was also statistically significant difference concerning small bowel affection, it was detected in all CD patients and in six cases (40%) of UC representing backwash ileitis ($p=0.006$), and large bowel involvement was detected in all UC patients and in six cases (66.7%) of CD ($p=0.04$). Haustral loss was detected in eight cases (53.3%) of UC and not detected in CD patients ($p=0.009$). No patient had small bowel obstruction, fistula or abscess formation. Demonstrative CD and UC cases are shown in (Figs. 2 and 3).

Our results revealed very good sensitivity, specificity, PPV, NPV and accuracy of mural diffusion restriction on DWI 100%, 80%, 76.2%, 100% and 90.5%, respectively, with higher accuracy, sensitivity and specificity compared to mural edema, with higher sensitivity and similar specificity compared to wall thickening (Table 6).

Correlation between endoscopic, clinical and MRE scores

Rationality of clinical, endoscopic and MRE scores/findings in recognition of severity of IBD utilizing pathology

Table 1 Clinico-epidemiologic features and disease presentation of total IBD cases and ulcerative colitis patients versus Crohn's disease patients

Parameters	All patients (n = 24)	Crohn's disease (n = 9)	Ulcerative colitis (n = 15)	P value
Age/Years	13.46 ± 3.51			
Mean ± SD		13.78 ± 3.67	13.27 ± 3.53	0.738
Sex (male/female)	11/13	6 (66.7)	5 (33.3)	0.113
		3 (33.3)	10 (66.7)	
Age of onset/years	11.75 (2–15.75)			
Mean ± SD		11.17 ± 3.92	11.48 ± 4.12	0.72
Duration of disease/years				
Median (range)	0.875 (0.08–6.0)	0.75 (0.08–6.0)	1.0 (0.25–5.0)	0.401
Duration of treatment/year				
Median (range)	0.575 (0.08–5.5)	0.3 (0.08–5.5)	0.75 (0.08–4.75)	0.858
Newly diagnosed cases	13 (54.2%)	5 (55.6%)	8 (53.3%)	0.915
Type of treatment				
Corticosteroids	12 (50%)	5 (55.6%)	7 (46.7%)	0.673
Immunon	21 (87.5%)	8 (88.9%)	13 (86.7%)	1.0
Remicade	6 (25%)	4 (44.4%)	2 (13.3%)	0.150
Pentasa	19 (79.2%)	6 (66.7%)	13 (86.7%)	0.325
Surgery	2 (8.3%)	2 (22.2%)	0 (0.0%)	0.130
Abdominal pain	17 (70.8%)	10 (66.7)	7 (77.8)	0.562
Diarrhea	9 (37.5%)	6 (40%)	3 (33.3)	0.744
Lower gastrointestinal bleeding	16 (66.7%)	11 (73.3%)	5 (55.6)	0.37
Weight loss or not gaining weight	20 (83.3%)	12 (80)	8 (88.9)	0.57
Perianal lesions	4 (16.7%)	2 (13.3)	2 (22.2)	0.614
Total case with extraintestinal manifestations	19 (79.2%)	10 (66.7)	9 (100)	0.051
Joint lesions	11 (45.8%)	7 (46.7)	4 (44.4)	0.915
Skin lesions	1 (4.2%)	1 (6.7)	0	1.0
Ocular lesions	4 (16.7%)	4 (26.7)	0	0.25
Fever	12 (50%)	7 (46.7)	5 (55.6)	0.673

Table 2 Mayo endoscopic score of ulcerative colitis cases (n = 15)

Mayo endoscopic score	Number
Normal or inactive disease	1 (6.7%)
Mild disease	3 (20%)
Moderate disease	7 (46.7%)
Severe disease	4 (26.7%)

as the gold standard were compared in (Table 6). Wall thickening and MRE severity score revealed higher accuracy as (95.8%) with 87.5%, 80%, 96% and 94.1% for sensitivity, specificity, PPV and NPV, respectively. The Endoscopic activity score revealed higher specificity (87.5%) and less sensitivity (85%) compared to MRE scores.

Our results revealed significant positive moderate and very high correlation between MRE score

Table 3 Simplified endoscopic activity score for Crohn's disease cases (n = 9)

SES-CD	Number
<i>Distribution of segments involved</i>	
Rectum	1 (11.1%)
Left colon	3 (33.3%)
Transverse colon	3 (33.3%)
Right colon	4 (44.4%)
Ileum	7 (77.7%)
<i>Number of segments affection per patient</i>	
0 Segment*	1 (11.1%)
1 Segment	3 (33.3%)
2 Segments	3 (33.3%)
3 Segments	0 (0.0%)
4 Segments	1 (11.1%)
5 Segments	1 (11.1%)

*In this case, Crohn's disease is initially diagnosed by MRE and confirmed by surgical biopsy from small intestine (jejunum)

Table 4 The simplified score for Crohn’s disease per highest segment involved per patient

Simplified score for Crohn’s disease per highest segment involved per patient (n = 9)	Result
Size of ulcers	
Descriptive findings (n %)	
None	2 (22.2)
Aphthous ulcers (0.1–0.5 cm)	4 (44.4)
Large ulcers (0.5–2.0 cm)	33.3
Very large ulcers (> 2 cm)	0 (0.0)
Median score (range)	1.1 (0–3)
Ulcerated surface	
Descriptive findings (n %)	
None	2 (22.2)
< 10%	3 (33.3)
10–30%	2 (22.2)
> 30%	2 (22.2)
Median score (range)	1.4 (0–3)
Affected surface	
Descriptive findings (n %)	
Unaffected segment	1 (11.1)
< 50%	4 (44.4)
50–75%	2 (22.2)
> 75%	2 (22.2)
Median score (range)	1.3 (0–3)
Presence of narrowing	
Descriptive findings (n %)	
None	5 (55.5)
Simple (can be passed)	0 (0.0)
Multiple (can be passed)	4 (44.4)
Cannot be passed	0 (0.0)
Median score (range)	0.89 (0–3)
Total score	
Descriptive findings (n %)	
Inactive disease (< 3)	2 (22.2)
Mild disease (3–9)	3 (33.3)
Moderate disease (9–12)	2 (22.2)
Severe disease (≥ 12)	2 (22.2)
Total score median(range)	6 (0–17)

and clinical scores among total cases and CD cases, respectively ($r=0.489$ and 0.806 , $p=0.015$ and 0.009 , respectively), while there was nonsignificant low correlation between both scores among UC cases ($r=0.291$, $p=0.292$) (Fig. 4).

There was significant positive correlation between MRE score and endoscopic scores in all groups with moderate correlation among total cases and UC cases, respectively ($r=0.559$ and 0.544 , $p=0.005$ and 0.036 , respectively) and very high correlation in CD cases ($r=0.790$, $p<0.001$) (Fig. 5).

Also, there was significant positive correlation between MRE score and pathological scores in all groups with very high correlation among total cases and CD cases, respectively ($r=0.814$ and 0.878 , $p<0.001$ and 0.002 , respectively) and high correlation in UC cases ($r=0.775$, $p=0.001$) (Fig. 6).

Discussion

Pediatric MRE is the optimal imaging method for detection IBD activity and has been progressively more utilized in the assessment of IBD in the last decade [22]. MRE is predicted to have better impact via detection of transmural disease not willing to endoscopic evaluation [10, 23].

Our MRE results revealed perfect inter-observer agreement concerning mural edema and wall thickening, substantial agreement for MRE severity score, mural diffusion restriction, vascular congestion and disease extent. There was statistically significant difference between UC and CD regarding mural edema. That was in line with previous meta-analysis study, revealing that mural thickening and DWI are characteristic for active inflammation [24]. Also, another retrospective study showed moderate to good inter-observer agreement for the inflammatory MRE features in CD patients [25].

Another recent study concluded similar results, they revealed that focal mural enhancement with wall thickening, mural edema and restricted diffusion were moderately correlated to CD [19]. Also similar results were conducted by another study, compared to MRE results in CD cases with surgically excised small bowel strictures and confirmed the presence of mural inflammation and damage [26].

Our results revealed that MRE severity score and wall thickening had higher accuracy for detection disease severity. This is in concordance with another study which considered mural thickening the primary imaging biomarkers of active inflammation on MRE in children with CD [27].

Pediatric UC is often more extensive at diagnosis than adults UC, it may present as pancolitis in 60% of patients [28]. Our results confirmed that MRE can detect terminal ileal changes in children with UC. The abnormal inflammation of the terminal ileum detected radiologically or endoscopically in UC patients is named as backwash ileitis [29], this ileitis occurs mainly in cases with extensive colitis [30].

Our results revealed substantial inter-observer agreement for mural diffusion restriction on DW images with higher sensitivity, specificity and accuracy than mural edema detected on MRE, that was in concordance with another study which revealed very good sensitivity, specificity, PPV, NPV and accuracy of diffusion

Table 5 MRE findings agreement between first and second observers

	First observer	Second observer	Kappa agreement (95% CI)	% Agreement
<i>MRE severity score</i>				
Mild	10	8	0.791 (0.569–1.0)	87.5
Moderate	13	12		
Severe	3	4		
<i>Wall thickening</i>				
Mild	8	9	0.862 (0.68–1)	91.7
Moderate	13	11		
Severe	3	4		
<i>Mural edema</i>				
Mild	5	4	0.846 (0.641–1.0)	91.7
Moderate	15	15		
Severe	4	5		
<i>Mural enhancement</i>				
Mild	3	4	0.560 (0.254–0.865)	75
Moderate	15	13		
Severe	6	7		
<i>Mural diffusion restriction</i>				
Mild	3	3	0.656(0.388–0.924)	79.17
Moderate	12	15		
Severe	9	6		
<i>Mesenteric edema</i>				
0	2	2	0.644 (0.396–0.891)	75.0
Mild	8	8		
Moderate	8	10		
Severe	6	4		
<i>vascular congestion, engorged vasa recta</i>				
No	8	4	0.66 (0.368–0.965)	83.3
Yes	16	12		
<i>Number of active LNs</i>				
0	3	4	0.527 (0.259–0.795)	66.7
1–2	8	7		
3–4	9	10		
≥ 5	4	3		
<i>Extent</i>				
Mild	3	4	0.783 (0.504–1.0)	85.71
Moderate	5	5		
Severe	6	5		

compared to contrast-enhanced MRI as 90%, 98%, 90%, 98% and 96%, respectively [14]. Also few other studies revealed similar results with good performance of DWI compared to contrast-enhanced MRE [13, 13].

Our results also confirmed that DWI can accurately detect inflamed bowel segments, that was in line with previous study which considered increased wall thickness and restricted diffusion were the better predictors of active inflammation [31].

The strength in our study is besides the perfect inter-observer agreement concerning mural edema and wall thickening with substantial inter-observer agreement for MRE severity score, mural diffusion restriction and disease extent, our results revealed high accuracy MRE compared to endoscopic findings and clinical activity scores with significant positive correlation. Thus, MRE provides an applicable adequate radiological assessment to predict severity of pediatric IBD. Incorporating the DWI analysis

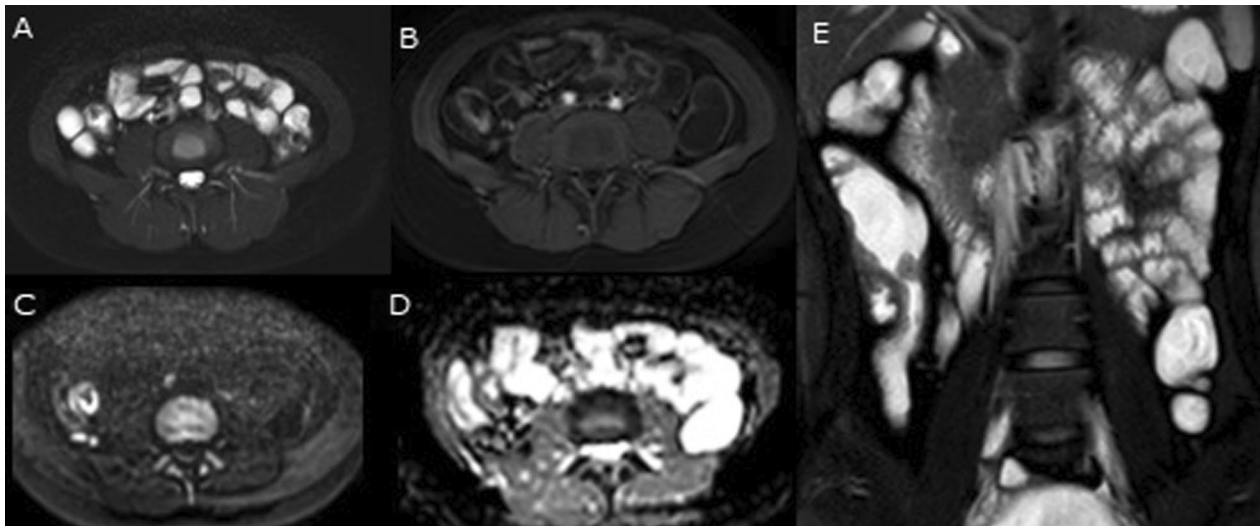


Fig. 2 Ten-year-old girl with Crohn's disease (mild activity according to MEGS): Axial T2-weighted image with fat saturation (A) revealed mild wall thickening of the terminal ileum (5mm) and mild hyperintensity (mural edema). Axial T1 post-contrast weighted image with fat saturation (B) revealed mild mural enhancement. Axial DWI (C) and corresponding ADC map (D) revealed mural diffusion restriction. Coronal T2-weighted image with fat saturation (E) revealed mild wall thickening and mural edema of terminal ileum and ileocecal region along length less than 10 cm

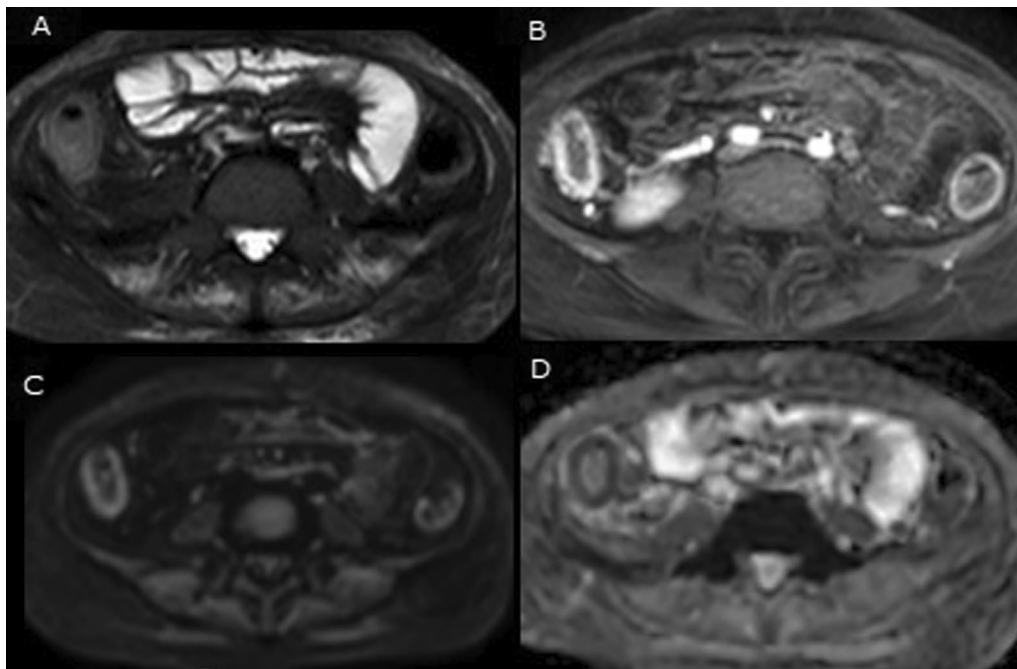


Fig. 3 Thirteen-year-old girl with ulcerative colitis with moderate activity: Axial T2-weighted image with fat saturation (A) revealed wall thickening (7 mm) and moderate hyperintensity (mural edema) of ascending and descending colon. Axial T1 post-contrast weighted image with fat saturation (B) revealed marked mural enhancement. Axial DWI (C) and corresponding ADC map (D) revealed marked mural diffusion restriction

in the MRE score may supply additional data with consequent clinical management especially in situations when IV contrast agents are contraindicated.

Our study has few limitations; firstly, the relatively small number of the patients. However, the number of our cases is greater than that in previous studies [20, 21]. Secondly, in the single-center design of our study,

Table 6 Validity of endoscopic, clinical and MRE scores/findings in detection of severity of IBD considering pathology as the gold standard

	Sensitivity%	Specificity%	PPV%	NPV%	Accuracy
MRE severity	87.5	80	96	94.1	95.8
Endoscopic activity score	85	87.5	73.8	92.3	91.7
Clinical activity score	81.2	81.2	92.9	70	83.3
Wall thickening	87.5	80	96	94.1	95.8
Mural edema	80	62.5	78.9	80.0	76.0
Mural enhancement	85	75	76.2	71.4	90.5
Mural diffusion restriction	100.0	80	76.2	100.0	90.5
Mesenteric edema	75.0	70.0	85.7	60.0	75.0
vascular congestion, engorged vasa recta	75.0	50.0	75.0	50.0	66.7
Number of active LNs	75.0	87.5	92.3	63.6	79.1

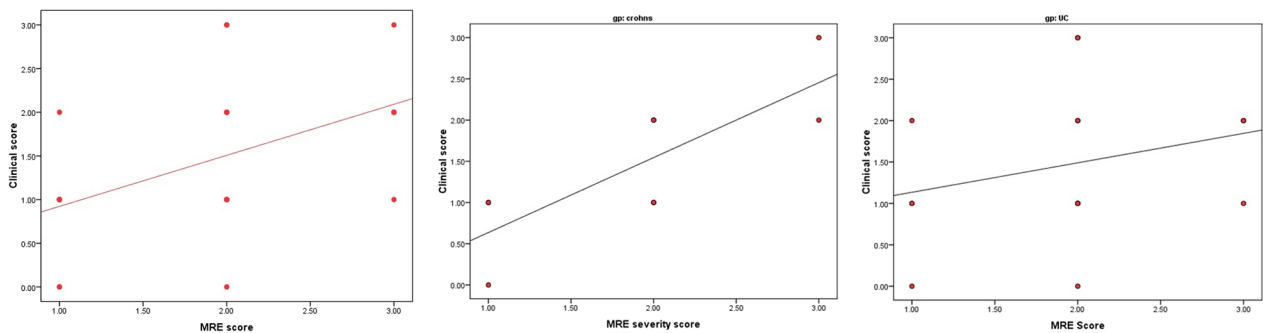


Fig. 4 Scatter diagram showing correlation between clinical scores and MRE severity scores among total cases (a), CD cases (b) and UC cases (c)

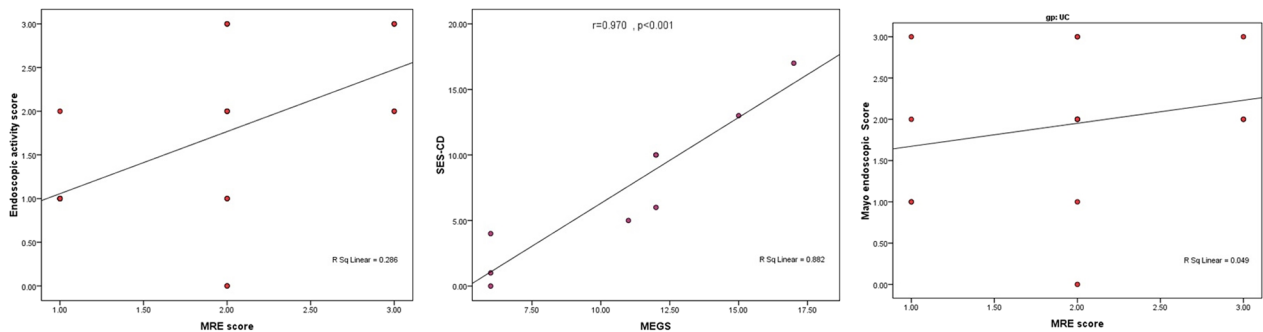


Fig. 5 Scatter diagram showing correlation between endoscopic scores and MRE severity scores among total cases (a), CD cases (b) and UC cases (c)

further multicenter studies could add more data. Thirdly, DWI interpretation was based on qualitative analysis without quantitative DWI analysis. Future further studies with quantitative evaluation could be helpful.

Conclusions

The magnetic resonance enterography is a reliable non-invasive imaging modality for diagnosis of pediatric IBD. MRE revealed significant positive very high correlation with clinical score, SES-CD and pathology activity among

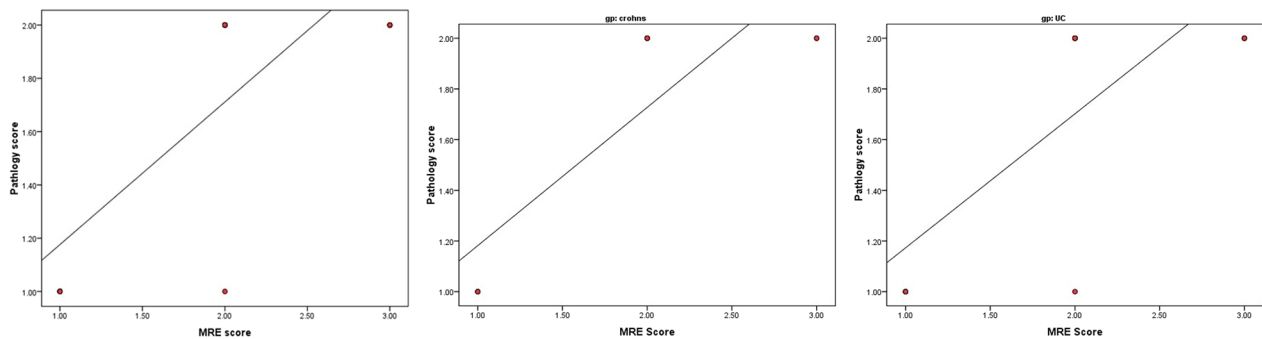


Fig. 6 Scatter diagram showing correlation between pathology scores and MRE severity scores among total cases (a), CD cases (b) and UC cases (c)

CD patients, while MRE revealed significant positive correlation only with Mayo endoscopic score and pathology activity among UC patients.

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Abbreviations

CD	Crohn's disease
DWI	Diffusion-weighted imaging
MRE	Magnetic resonance enterography
MEGS	Magnetic resonance enterography global score
SES-CD	Simplified endoscopic activity score for Crohn's disease
UC	Ulcerative colitis

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Author contributions

All authors have read and approved the manuscript. Study concept and design was proposed by GAS and AAA. SIA and GAS helped in database search. GAS and AAA contributed to image analysis and interpretation of data. Clinical assessment was done by SIA, AM and MAS. AM was involved in endoscopic analysis. GAS and AM helped in revision of the manuscript.

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Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Declarations

Ethics approval and consent to participate:

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The study was approved by the Institutional review board of Mansoura University (Approval No: MS.17.12.37). A written informed consent was obtained from all patients.

Consent for publication

The participants in the study were informed and consented the possibility of research publication.

Competing interests

The authors declare that they have no competing interest.

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