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Detection of intramural fat accumulation by 3D-Dixon-Caipirinha-Vibe and the contribution of this technique to the determination of the chronicity of Chron's disease

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ABSTRACT

Objectives: In this study; we aimed to evaluate the efficacy of the 3D-Dixon-Caipirinha-Vibe fat images in detecting intramural fat accumulation (IFA) and contributions of 3D-Dixon-Caipirinha-Vibe in the management of patients with Chron's disease.
Methods: Eighty-five patients who had a 3-tesla MR enterography (MRE) with the 3D-Dixon-Caipirinha-Vibe technique were included. Wall thickness, ADC-value, intramural edema, presence/extension of IFA, and contrast-material enhancement of the affected segments were examined. Findings of MRE were compared statistically with clinical, laboratory, endoscopy, and pathological exams.
Results: The presence of IFA was more common in patients with chronic active and chronic inflammation than only active inflammation and normal cases. Patients with IFA had a longer disease duration than patients without IFA. IFA-containing segment lengths of patients with chronic active inflammation and chronic inflammation were found to be longer than those with active inflammation. It was found that patients whose pathology results were reported as active inflammation contained less IFA than patients with chronic inflammation.
Conclusions: The presence of IFA is strongly related to chronicity. 3D-Dixon-Caipirinha-Vibe is a fast, easy, and useful method for detecting IFA and evaluating Chron's disease.

1. Introduction

The use of MR enterography (MRE) has become very widespread for the evaluation of small bowels due to its non-invasive nature and the absence of radiation, and the contribution of providing useful data in terms of intestinal and extraintestinal pathologies [1,2]. Accurate determination of active or chronic phase is necessary for optimal management of Chron's disease [3].

By modifying the phase encoding sampling strategy in MRI, aliasing is shifted in a way that exploits the underlying receiver array more efficiently [4]. The result is improved image quality and decreased motion/respiratory artifacts with a more robust and homogenous reconstruction in controlled aliasing in parallel imaging results in higher acceleration [4]. This technique is called Caipirinha, and it is a recently introduced parallel imaging technique [5]. Some up-to-date facilities are necessary for optimal usage of the Caipirinha (e.g., advanced coil designs with an increased number of coil elements and higher coil density and powerful hardware for image reconstruction) [4]. It contributes to the reduction of the examination time and the artifacts, and the improvement of the image quality [6].

Simultaneously usage of the Caipirinha, Dixon, and volumetric interpolated breath-hold examination (VIBE) techniques has also been exploited to provide higher temporal resolution while preserving diagnostic image quality for abdominal imaging [4,5]. This approach provides high diagnostic accuracy, improved SNR/CNR, and the reduction of the examination-time/artifacts [4].

Submucosal fat deposition (also called a fat halo sign) on routine CT or MR images is a finding of chronic inflammatory bowel disease (IBD). The presence of intramural fat accumulation is important because the determination of this finding may contribute to an accurate, fast, and easy diagnosis of Crohn's disease. We aim to investigate the feasibility and contribution of 3-tesla (3 T) 3D-Dixon-Caipirinha-Vibe fat subgroup

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Table 1
3-tesla MRE protocol of the study.

Sequences/ Parameters	T2-HASTE-FS	T2-HASTE	3D-DIXON-CAIPIRINHA-VIBE	3D-T1-VIBE	DWI
TR/TE (ms)	1000/99	1000/99	4.21/1.34–2.57	4/1.74	4100/54
Slice thickness (mm)	5	5	1.5	2.2	5.5
FOV* (mm^2)	400	400	450	400	380
Acquisition time (*sec.*)	38	38	11	13 × 4 (for multiphase imaging)	115
NEX	1	1	1	1	5
Slice number	26	26	88	64	24
Flip angle (°)	139	139	9	9	–
Imaging plane	Axial+coronal	Coronal	Coronal	Coronal	Coronal
Distance factor (%)	10	10	–	–	20
PAT factor	3	3	3	3	3
PAT mode	GRAPPA	GRAPPA	CAIPIRINHA	GRAPPA	GRAPPA
Voxel size (mm^3)	1.25 × 1.25 × 5	1.25 × 1.25 × 5	1.4 × 1.4 × 1.4	1.25 × 1.25 × 2.2	1.42 × 1.42 × 5.5
Fat saturation	+	–	+	+	+
Base resolution	320	320	320	320	134
Matrix	270 × 320	270 × 320	208 × 320	203 × 320	108 × 134

Abbreviations: TR/TE: Time of repetition /Time of echo; NEX: number of excitations; FOV: field of view; PAT: parallel acquisition technique; GRAPPA: generalized auto calibrating partially parallel acquisitions; CAIPIRINHA: controlled aliasing in parallel imaging results in higher acceleration.

Table 2
Results of definite diagnosis session of the cases.

Diagnosis	Number	%
Active inflammation (AI)	34	40
Chronic active inflammation (CAI)	35	41.2
Chronic inflammation (CI)	7	8.2
No abnormality	9	10.6
Total	85	100.0

Table 3
Relationships between MRE results and intestinal wall thickness (Kruskal Wallis test). There are significant differences between all categories ($P = 0.001$).

The bowel wall thickness of the affected segment (mm)					
MRE results	Mean	SD	Median	Min-max	*P*-value
Active inflammation (AI)	5.64	2.55	4.50	3-13	
Chronic active inflammation (CAI)	6.88	2.44	6.00	3–12	**0.001**
Chronic inflammation (CI)	3.57	0.78	3.00	3–5	

Table 4
Relationships between MRE results and the affected bowel segment length according to the Kruskal Wallis test.

	The affected bowel segment length (mm)			
MRE results	Mean	SD	Median	Min-max
Active inflammation (AI)	94.19	79.23	50	20-300
Chronic active inflammation (CAI)	172.42	111.97	200	25-400
Chronic inflammation (CI)	187.85	362.23	25	20-1000

images in the determination of chronicity and evaluation of Chron disease. According to our knowledge, there is no study on this subject in the literature.

2. Materials and methods

The ethics committee approval was obtained (decision number: E1-20-858, 2nd July 2020) for this study. Patients who have (or suspected) Chron's disease underwent 3-tesla MRE in 4 years were included in the study. After a retrospective analysis of these patients and the MRE images, 85 patients with the MRE and 3D-Dixon-Caipirinha-Vibe sequence were included in this study.

2.1. Inclusion criteria

- Patients have Crohn's disease or Crohn's disease suspicion based on gastroenterologist notations in the clinical records.
- Patients with routine MRE and 3 T 3D-Dixon-Caipirinha-Vibe technique, simultaneously.
- Clinical information, ileocolonoscopy, and/or pathology results available in our hospital system.

2.2. Exclusion criteria

- Patient without detailed clinical and follow-up information,
- Patients with incomplete or insufficient MRE images due to artifacts or inadequate bowel distention.

2.3. MRE protocol

The patients were recommended to drink 50 + 50 ml of laxative diet solution (X-M diet, Yenisehir laboratories, Ankara) the night before and on the morning of the MRE. For bowel cleansing, solid food consumption was prohibited 12 h before MRE, and patients were asked to only consume fluids. It has been explained that for an optimal MRE examination, it is necessary to drink the entire oral contrast agent, and it should be finished in approximately 50 min.

We used 1500 ml as a biphasic oral contrast agent mixture containing 10 g of methylcellulose, 250 ml lactulose (Duphalac® 670 mg/ml, Abbott), 225 mL of low dose (4.9%) barium sulfate (*E-Z*-Cat; E-Z-EM, Inc., Quebec, Canada), and water for the MRE exams. MRE was started approximately 5-10 min after the patient had ingested the entire oral contrast agent mixture. 20 mg hyoscine N-butyl-bromide (Buscopan, Boehringer Ingelheim, Ingelheim am Rhein, Germany) was administered intravenously before MR enterography to decrease intestinal peristalsis. Then, we administer 0.2 mg intravenous gadoterate dimeglumine (Dotarem; Guerbet, Roissy, France) per kilogram of body weight at an injection rate of 3 ml/s. The same 3 T MR unit (Skyra, Siemens Healthcare, Germany) was used for all MRE exams. MRE acquisition details were given in Table 1. Coronal plane 3D-Dixon-Caipirinha-Vibe sequence was applied with the same parameters before and after intravenous contrast media (arterial, portal, and late phases).

2.4. Evaluations of the MRE data

All patients were listed on the study worksheet. MRE images were randomly evaluated by two (at least 4 years experienced for MRE with 3D-Dixon-Caipirinha-Vibe) radiologists using the PACS system. The evaluators did not know the patient history and laboratory findings, but

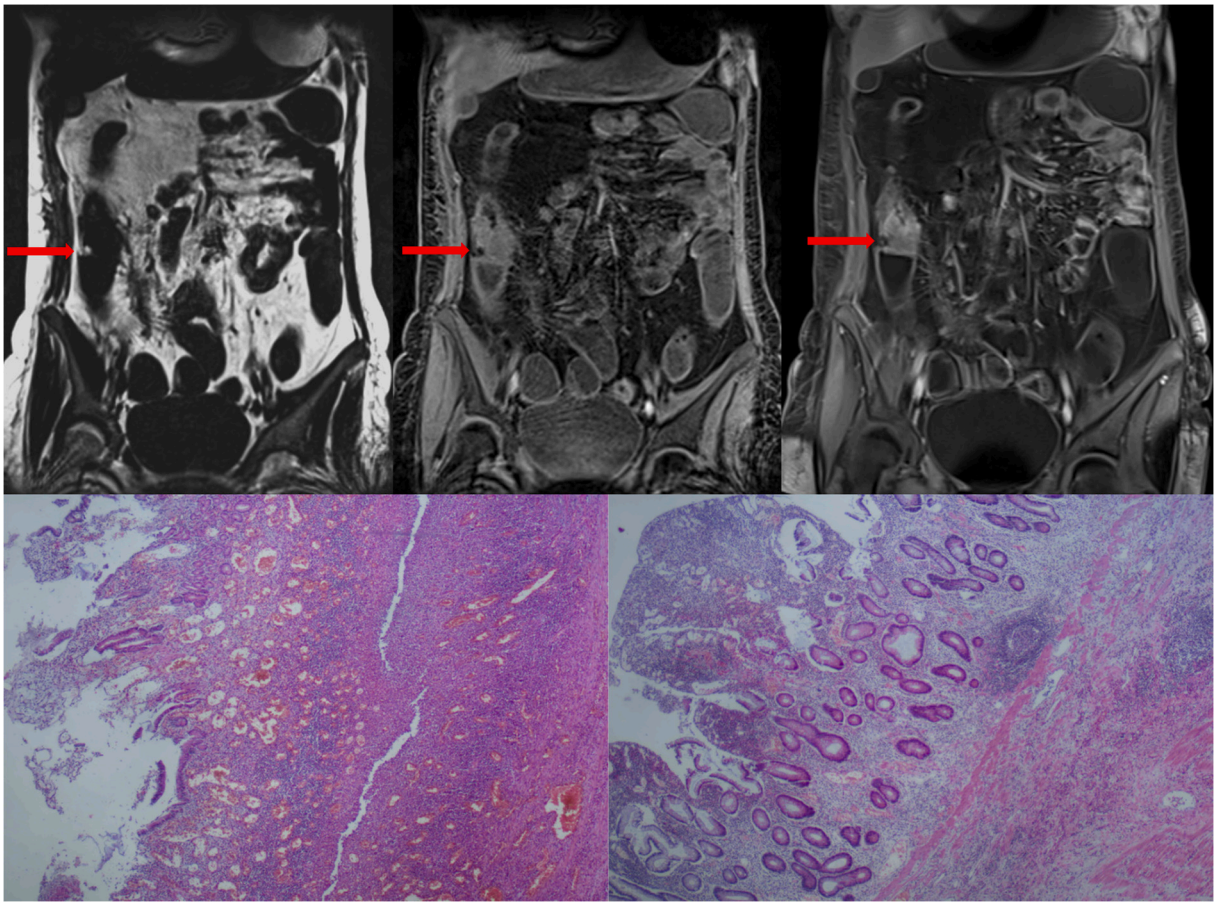

Fig. 1. 3D-Dixon-Caipirinha-Vibe fat (upper left), contrast-material enhanced 3D-Dixon-Caipirinha-Vibe water (upper middle) and 3D-vibe (upper right) images show intramural fat accumulation (arrows) of a 21-year-old female. Contrast material enhancement, elevated wall thickness, and prominent vessels (comb sign) were also observed on the images. MRE and surgical pathology exams are reported as chronic active inflammation. In the microscopy images of the resection specimen (Hematoxylin & Eosin, 4 × 10, small intestine tissue), ulceration and loss of crypt in the surface epithelium, loss of mucus in the crypts, submucosal fibrosis, and transmural inflammation are observed (lower left). Lymphoid aggregates belonging to transmural chronic inflammation are also seen (lower right).

they knew the goals of the study. Any disagreement between the readers was resolved by consensus. The disease duration and clinical/laboratory findings of the patients were extracted from our gastroenterology department records.

The presence of the below-mentioned findings in the affected bowel wall (usually the ileocecal valve or terminal ileum) were evaluated on MRE images and scored as the present, absent, and equivocal.

a- Bowel wall edema on T2W fat-suppressed images,
b- Intramural fat accumulation (IFA) on the 3D-Dixon-Caipirinha-Vibe fat images,
c- Restricted diffusion on b800 images.

On MRE images, the presence of mural hyperintensity compared to psoas muscles (bowel wall edema) accompanying wall thickening (>3 mm) on T2W images, prominent mural contrast enhancement (higher than the normal loops but less than the nearby vessels) on post-contrast T1W images, restricted diffusion in the affected segment(s), vascular engorgement, and/or mesenteric lymphadenomegaly with diffusion restriction in the affected bowel walls on b800 images were considered as active inflammation (AI) based on the literature [1,7]. Patients with fibrotic changes (intramural mural hypointensity on T1 and T2W images) and mural thickening/enhancement, and/or restricted diffusion in the affected segment(s) were classified as chronic active inflammation (CAI, also called active inflammation with sequela of prior disease). The presence of fistulas, abscesses and other complicating findings were also assessed. Cases without AI findings but with fibrotic changes were accepted as a chronic disease (CI, also called sequela without inflammation). The patients without bowel abnormality on MRE sequences were considered normal.

Intramural hyperintensity (longer than 3 mm) on 3D-Dixon-Caipirinha-Vibe fat images was defined as IFA. The length and maximum wall thickness, and ADC values (using a circular intramural ROI) of all affected segments were also measured on MRE images. The affected segment measurements were made by a less experienced reader. If present, skip lesions were not considered during the measurements. The same procedure was used for measuring intramural fat length. Discrepancies (in 8 cases, 9%) related to the IFA and affected segment assessments or definite diagnosis were resolved with agreement by all authors in a consensus session.

After assessments of MRE images, endoscopic biopsy (endoscopy result obtained in the same month in 43 patients) and surgical (one case) results were used as gold-standard methods for comparisons. In the remaining 41 patients, the authors evaluated findings of all available clinical/laboratory, endoscopy, MRE, and pathological exams of the patients in a separate definite diagnosis session, and results of this session were accepted as the gold standard test for the statistics. Crohn's disease activity index (CDAI) > 220 and CRP > 10 mg/l are the positive signs for active disease [8]. A decrease of 100 points or CDAI <150 was accepted in favor of chronic disease [8]. When there were discrepant results from the various tests, final diagnoses for AI, CAI, CI were reached with consensus. Any discrepancies (in 9 cases) between the authors were resolved through discussion until consensus was reached.

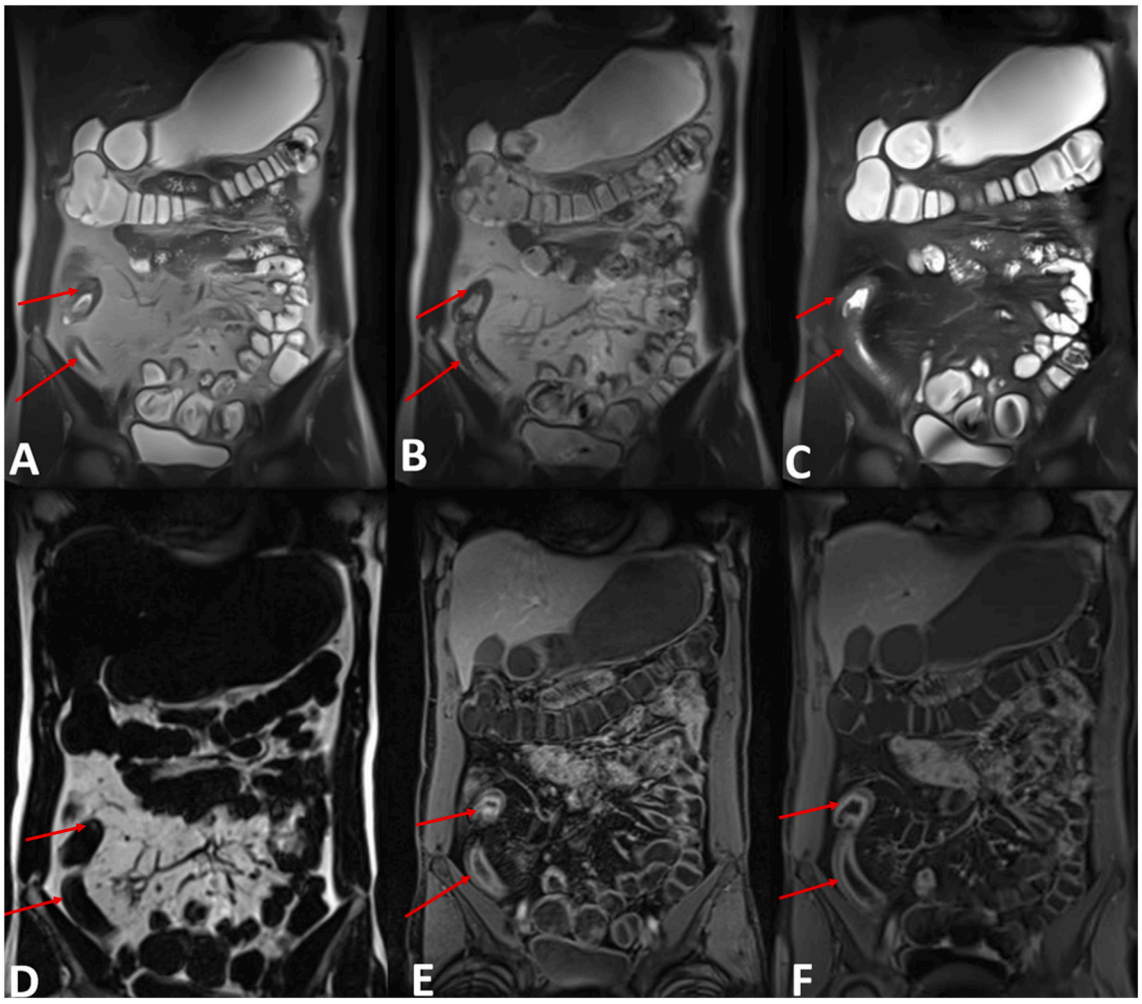

Fig. 2. Coronal T2W (A-C), fat (D), and postcontrast T1W (E, F) MRE images of a 36-year-old male with newly diagnosed endoscopy proven active ileitis. Wall edema on T2W without clearly visible intramural fat accumulation and contrast-material enhancement in the whole terminal ileum (arrows).

2.5. Statistics

Statistical analyzes were performed with the SPSS 21.0 program (IBM Corp. Released in 2012. IBM SPSS Statistics for Windows, Version 21.0 Armonk, NY: IBM Corporation). Descriptive statistics are given by number and percentage. Measurement data were evaluated with the Kolmogorov-Smirnov test and histogram in terms of normal distribution and presented with mean, standard deviation, median, minimum-maximum values. In statistical evaluation, the Pearson chi-square test was used to compare quantitative data, the Mann-Whitney *U* test was used in paired groups to compare quantitative data and the Kruskal-Wallis test was used in triple groups.

Spearman correlation test was used to examine the correlations. The correlation coefficient r varies between −1 and +1. +1 indicates a total positive agreement, 0 indicates no harmony, and −1 indicates a total negative agreement. Bonferroni correction was applied to detail the significance between categories and to find out from which groups the relationship between them originated. The consistency between the MRE examinations and the gold standard test was examined with Cohen's Kappa test. The κ coefficient is normally between 0 and 1 (0: indicates a chance compromise, 1: indicates perfect compatibility). The statistical significance value was accepted as 0.05.

3. Results

Forty-nine (57.6%) of the cases were men and 36 (42.4%) of the cases were women. The mean age of the participants was 41 (median 39, min-max: 12-71, SD: 13) years. Internal fistula, abscess, and prominent mesenteric vessels (comb sign) were detected in 5, 2, and 18 patients, respectively.

According to definite diagnosis sessions, 40% of the patients were consistent with AI, 41% were CAI, 8% were CI, and 11% were normal (Table 2). The sensitivity, specificity, PPV, NPV, and accuracy values of MRE in detecting active disease were 92.11%, 66.67%, 95, 57, and 88.64%, respectively.

The mean and median intestinal wall thicknesses of the cases were 5.6 ± 2.7 mm and 5 mm (min-max: 2-13), respectively. Also, the relationship between inflammation type and intestinal wall thickness is given in Table 3.

It was found that the affected bowel segment length was longer in patients with CAI compared to patients with AI and CI ($p < 0.001$ and p:0,034, respectively (Table 4). There was no statistically significant difference between patients with CI and patients with AI-related to affected bowel segment length (p:0.366).

While IFA was detected in 30 patients, it was not detected in 49

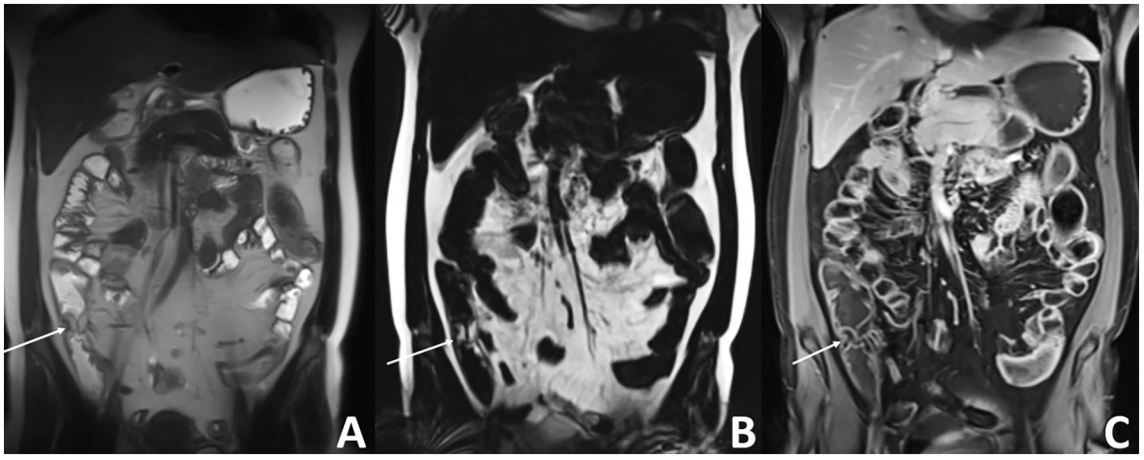

Fig. 3. MRE findings of active ileitis on a chronic basis (CAI) of a 40-year-old female with 8 years of Chron's disease history. Bowel wall thickening and intramural edema on T2W (A), intramural fat accumulation on fat (B), and contrast material enhancement on T1W coronal images (C) were observed around the pericecal area (arrows).

cases, and it was uncertain in 6 patients (Figs. 1–3). Patients with IFA (mean: 1779 ± 2202, median: 1186, range: 0–7410 days) had significantly longer disease duration than patients without IFA (mean: 716 ± 1019, median: 30, range: 0–4350 days) (p: 0.041). IFA length was longer in patients with CI and CAI compared to AI patients (p:0.001 and $p <$ 0,001 respectively) (Table 5). IFA was present in most of the patients with CAI and half of the patients with CI. However, IFA was not observed in patients with AI (Table 6) (Figs. 4 and 5). The distributions of the IFA were given in Table 7.

ADC values were significantly higher in patients with CI than patients with AI (p:0,037) and CAI (p:0.024) (Table 8).

There were statistically significant positive correlations between disease duration, IFA length, intestinal wall thickness, and affected bowel segment length (Table 9). The disease duration of our steroid user patients without IFA was 9, 42, 48 months, respectively (112 months for the patients with IFA).

The diagnoses based on pathological findings are given in Table 10.

Table 5
Relationships between intramural fat length and inflammation type according to the Kruskal Wallis test.

	Intramural fat length (mm)				
MRE results	Mean	SD	Median	Min-max	P-value
Active inflammation (AI)	0.48	2.69	0	0–15	**<0.001**
Chronic active inflammation (CAI)	46.72	74.12	30.00	0–350	
Chronic inflammation (CI)	70.00	167.85	0	0–450	

Table 6
Relationships between MRE results and presence of intramural fat according to the Kruskal Wallis test.

	Presence of intramural fat						
	None		Doubtful		Present		P-value
MRE result	n	%	n	%	n	%	
Active inflammation (AI)	34	100,0	0	0,0	0	0,0	**<0.001**
Chronic active inflammation (CAI)	2	5,7	6	17,1	27	77,2	
Chronic inflammation (CI)	4	57,1	0	0,0	3	42,9	

There was a low level of agreement between pathological and MRE results (Table 11).

4. Discussion

Crohn's disease is an idiopathic and chronic inflammatory bowel disease with full-thickness intestinal wall involvement that mostly affects the young population [5]. Cross-sectional radiological methods play a key role in making and confirming the diagnosis, evaluating disease extent, determining/managing complications, and evaluating treatment response [1]. The need for frequent imaging without radiation makes MRE the most popular imaging method [2,7].

In parallel with the literature, a positive significant correlation was found between active inflammation and wall thickness in our study [7–12]. We detected the comb sign in 18 patients, and all these patients had signs of active disease on MRE images. According to our data, ≥5 mm wall thickness with edema, contrast-material enhancement, and comb sign can be used as a criterion for active disease (AI).

In a meta-analysis, the sensitivity or specificity of MRE is between 72 and 93% and 67–92% [11]. In our study, the sensitivity, specificity, and accuracy values of MRE in detecting active disease were 92.11%, 66.67%, and 88.64%, respectively. These values are compatible with the literature. We could not calculate these values for the detection of chronic disease due to endoscopy-based pathological samples do not contain all bowel wall layers.

We detect a low level of agreement between pathological and MRE results, but we found a moderately high accuracy for MRE in detecting active disease. Although pathological examination from endoscopy is generally accepted as the gold standard diagnostic method for the diagnosis and activity evaluation of Crohn's disease [12]. Conventional endoscopy is not perfect or adequate for the evaluation of patients with Crohn's disease. It has some disadvantages, such as inadequacy in viewing all segments of the small bowels or all layers of the bowels [12]. This may be a reason for the above-mentioned condition.

In our study, ADC values of affected segments of the patients with AI and CAI were lower than in patients with CI and normal cases. Diffusion-weighted imaging (DWI) does not require intravenous contrast media administration, and its efficacy for detecting small intestinal inflammation is comparable to that of contrast-material enhanced MRE [12,13]. Non-contrast MRE exams with DWI are applicable options to evaluate active inflammation in patients with Crohn's disease [12]. However, there is no consensus in the literature for findings or effectivity of DWI in CI or CAI [12]. Non-contrast MRE exams (T2W, 3D-

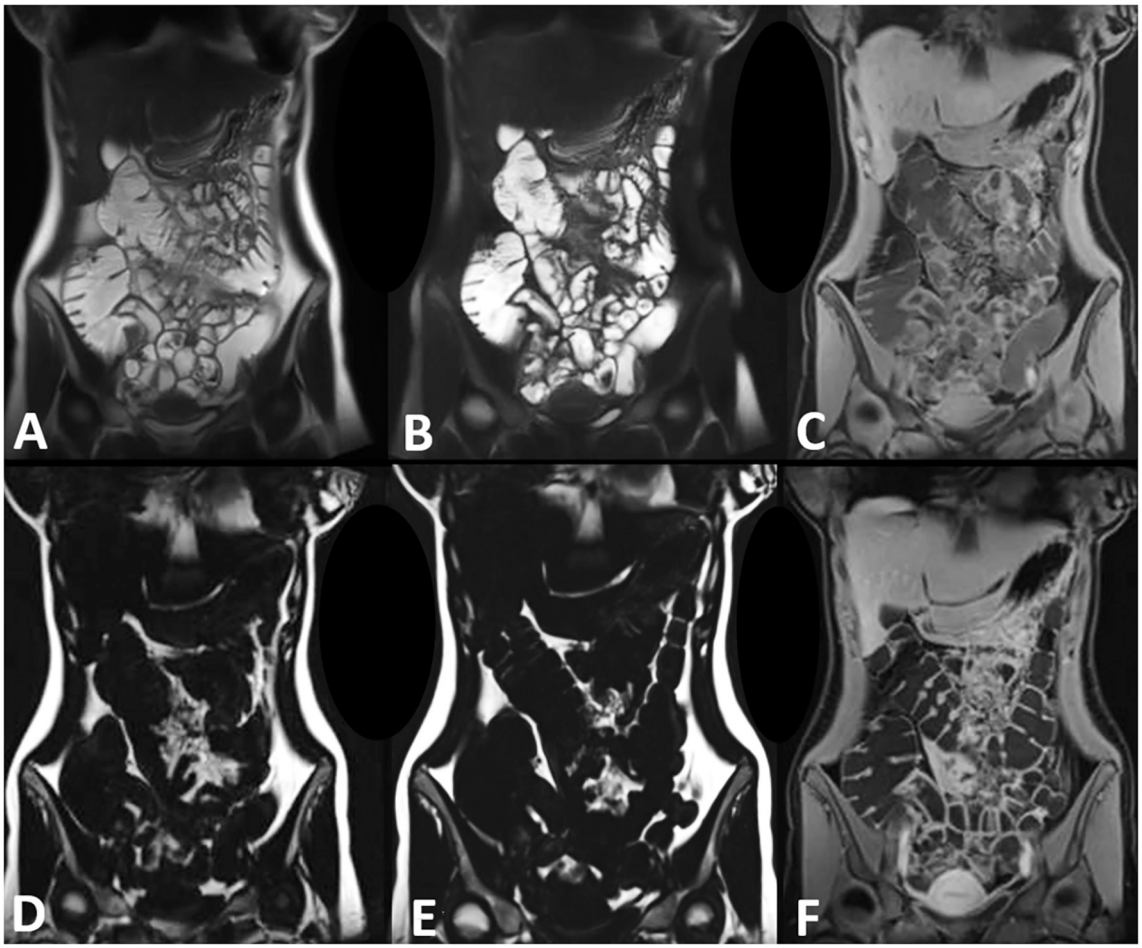

Fig. 4. Coronal MRE images of a patient without IBH obtained from the ileocecal valve level. HASTE (A), fat-suppressed HASTA (B), non-contrast T1W (C), fat images (D, E) postcontrast T1W (F) images show that there is no abnormality in the bowels.

Dixon-Caipirinha-Vibe T1W water, and 3D-Dixon-Caipirinha-Vibe fat) with DWI may increase the efficiency of DWI and confidence of the radiologist with the aid of the IFA sign. Larger studies are needed on the use of DWI and 3D-Dixon-Caipirinha-Vibe in the diagnosis of IBH.

IFA (fat halo sign) is mostly seen in the chronic phase of IBD [14–16]. Also, IFA may be seen after transplantation or cytoreductive chemotherapy, long-standing steroid administration, radiation therapy, and pseudomembranous colitis [17–22]. The relationship between the above-mentioned conditions and IFA is not clear. IFA plays a role in inflammation in IBD [17–22]. In our study, we detected IFA in only one of five steroid user Crohn's patients. We evaluated one of them as uncertain, and we did not detect IFA in the other three patients. In these five steroid users of Crohn's patients, the disease duration of the patient with IFA was longer than the other steroid user patients.

When IFA is seen simultaneously in the small and large intestine, it is specific evidence for Crohn's disease [17,18]. We found IFA in 77% of CAI and 43% of CI patients (Table 6). Philpotts et al. and Amitai et al. were detected the submucosal fat deposition at 8% and 17% in Crohn's disease, respectively [19,23]. Intramural fat in the ileocecal valve can be a normal finding if no IBD [24]. The exact incidence of incidental IFA is not known.

The IFA detection rate in our study is 35.3%. Ten percent of these patients were suspected, and 90% of the patients were definite Chron's disease. We did not find IFA in patients with active inflammation without sequela of prior disease. All patients with IFA had a chronic disease (CI or CAI) in our study. Fullard et al. examined surgical specimens and they found increased submucosal fat in 40% of Crohn's patients [22]. They suggested that IFA has a role in bowel inflammation [22]. Chronic inflammation, the subsequent cell death, and defective wound healing occurring that causes degradation of the extracellular matrix (ECM), tissue damage, and abnormal tissue proliferation in the submucosa of patients with IBH may also be responsible for IFA etiopathogenesis [25].

We found that patients with IFA had longer disease durations than patients without IFA. Jones et al. and Amitai et al. detected the IFA is seen in long-term disease as observed in our study [19,20]. Our data and the literature show that the presence of IFA favors chronicity in Chron's disease. We also found a correlation between disease duration and the IFA length.

The location of the IFA is the ileocecal valve in most of the IFA positive cases. In cases with severe disease manifestations or skipped involvement, the sign of IFA was also present in some regions other than

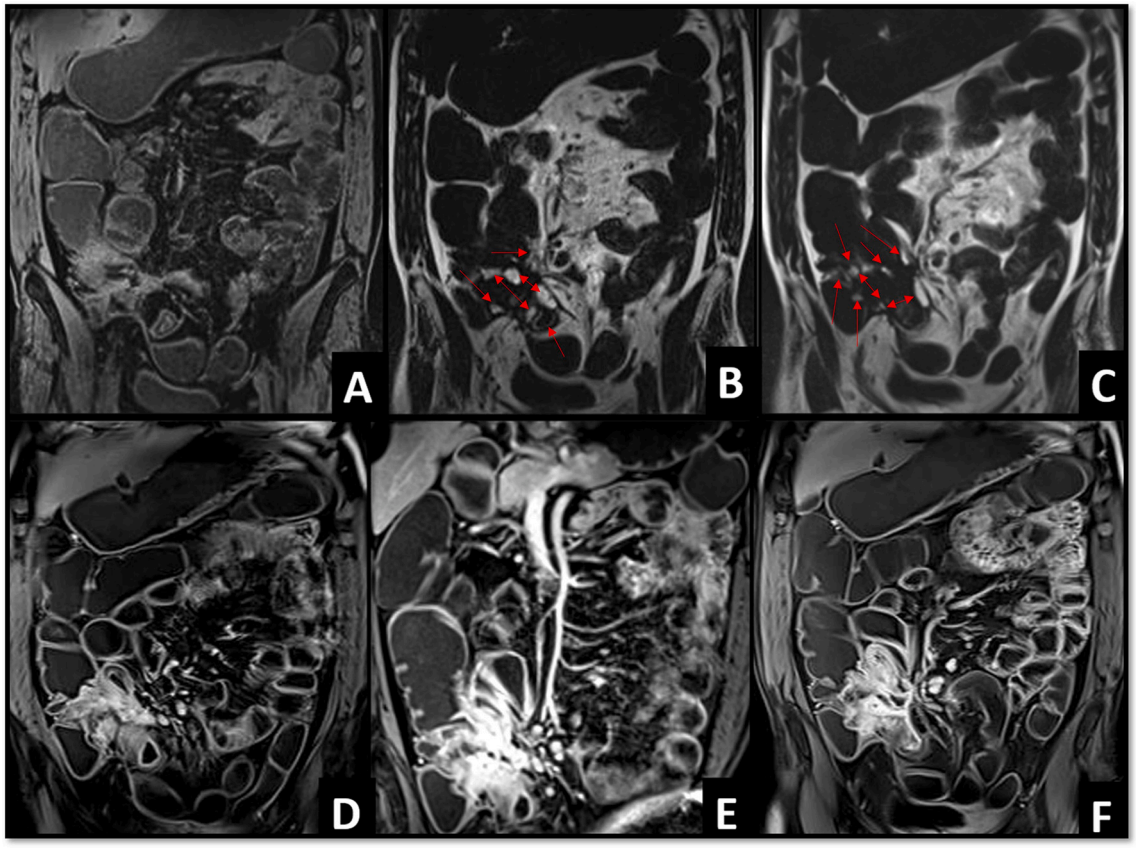

Fig. 5. Non-contrast T1W (A), 3D-Dixon-Caipirinha-Vibe fat (B, C), and post-contrast T1W (D–F) images of a male with chronic active Crohn's disease. There are multiple intramural fat accumulations (some of them protruding to the lumen) in different bowel segments (arrows in B and C).

Table 7
Distributions of the intramural fat on MRE images (Where intramural fat was seen the most, only that region was recorded in the table)

	Segments	Number	%
Intramural fat	Ileocecal valve	30	51
	Terminal ileum	17	29
	Cecum	4	6.7
	Descending colon	3	5
	Other ileal segments	3	5
	Transverse colon	2	3.3

Table 8
Relationships between MRE results and presence of ADC (mm^2/s) values of bowel wall according to the Kruskal Wallis test.

	ADC values (mm2/s)				
MRE result	Mean	SD	Median	Min-max	P-value
Normal	1617.77	274.41	1558	1257–1968	**0.006**
Active inflammation (AI)	1311.87	266.69	1281	844–1892	
Chronic active inflammation (CAI)	1281.96	252.23	1236	883–1898	
Chronic inflammation (CI)	1548.85	324.91	1599	930–1914	

Table 9
Correlations between bowel wall thickness, affected segment length, intramural fat length, and disease duration (Spearman correlation test results).

		Bowel wall thickness	Affected segment length	Intramural fat length
Disease duration	r	0.267	0.251	0.232
	p	**0.014**	**0.020**	**0.032**
Bowel wall thickness	r	–	0.826	0.468
	p	–	**<0.001**	**<0.001**
Affected segment length	r	–	–	0.548
	p	–	–	**<0.001**

Table 10
Presence of inflammation based on pathological examination results.

Pathological exam results	Number	%
Normal	3	6.8
Active inflammation (AI)	14	31.8
Chronic active inflammation (CAI)	23	52.3
Chronic inflammation (CI)	4	9.1
Total	44	100.0

the ileocecal valve (Fig. 5). This was an important finding that we did not observe in normal cases, and it indicates that the disease was in the chronic phase or not in the early phase.

The voxel size of our 3-tesla 3D-Dixon-Caipirinha-Vibe sequence is $1.4 \times 1.4 \times 1.4\ mm^3$. Dixon-Caipirinha-Vibe with isotropic small voxel

Table 11
Relationships between MRE and pathological results according to Cohen's Kappa test.

MRE results	Pathology results									
	Normal		AI		CAI		CI			
	n	%	n	%	n	%	n	%	κ	P-value
Normal	2	50.0	1	25.0	1	25.0	0	0.0	**0.397**	**<0.001**
Active inflammation (AI)	0	0.0	11	55.0	8	40.0	1	5.0		
Chronic active inflammation (CAI)	0	0.0	2	11.8	13	76.4	2	11.8		
Chronic inflammation (CI)	1	33.3	0	0.0	1	33.3	1	33.4		

size leads less the partial volume effect, allows for the reduction of motion artifacts with improved lesion characterization, and provides increased spatial/temporal resolution [6,26]. Parallel imaging, undersampling, view sharing, and Dixon water-fat separation are combined in 3D-Dixon-Caipirinha-Vibe [4]. The use of the Dixon technique results in improved SNR and CNR on reconstructed water and fat-only images [4]. Four separate image series; namely in-phase, out-of-phase, fat only, and water only images are obtained by making calculations from a single 3D-Dixon-Caipirinha-Vibe acquisition obtained within a single breath-holding. According to our experiences, the 3D-Dixon-Caipirinha-Vibe fat images are very useful for the detection of tiny IFA. Besides, contrast-material enhanced 3D-Dixon-Caipirinha-Vibe water images are more efficient than routine 3D-Vibe images for the detection of active disease and complications, especially in early Chron's disease. Shortly, contrast-material enhanced 3D-Dixon-Caipirinha-Vibe water images are efficient for detecting the active disease, and 3D-Dixon-Caipirinha-Vibe fat images are very useful for the evaluation of the chronicity.

The present study has some limitations, including its retrospective nature and lack of surgery, endoscopy, and/or full-thickness pathology results for all cases. However, this limitation would be valid for many MRE studies in the literature. We found ADC values were higher in patients with CI versus AI and CAI. There may be a significant relationship between IFA and ADC. The cases were obtained from a single tertial center and study subgroups had a relatively small size. The artifacts caused by respiration or bowel movements during MRE may affect the judgments. Finally, inter/intra-rater agreement results of IFA measurements were missing in our study. Further comprehensive studies are warranted to clarify the importance of IFA and verify the contributions of the 3D-Dixon-Caipirinha-Vibe technique in evaluating Chron's disease.

5. In conclusion

MRE findings are different in acute or chronic stage Crohn's disease. 3D-Dixon-Caipirinha-Vibe is a useful and fast method for the evaluation of small intestine imaging, which is difficult to reach with endoscopy. IFA is a useful parameter that shows the chronicity of Chron's disease.

Ethical approval

All procedures performed in the studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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None.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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