Research article

Small bowel stricture is associated with abnormal motility on the cine MRI sequence in patients with Crohn's disease

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A B S T R A C T

Purpose: A multiphasic cine sequence performed during magnetic resonance enterography (MRE) has been shown to increase diagnostic accuracy of MRE demonstrating limited movement in inflamed intestine in patients with Crohn's disease (CD). Our aim was to confirm in our study population that intestinal inflammation was associated with decreased motility and determine if factors suggestive of complicated disease such as the presence of a stricture or fistula were associated with decreased motility on the MRE cine sequence.
Methods: This was a retrospective study of 59 patients (mean age 40.8 ± 16.1) with Crohn's disease who had a small bowel lesion on MRE. Two gastrointestinal radiologists independently scored MRE findings using a qualitative, subjective scoring system. Univariate and multivariable ordered logistic regression models were used to evaluate the associations between cine sequence score, radiologic image findings, and clinical data.
Results: On univariate analysis, radiologic findings reflecting active inflammation, the presence of a stricture, and penetrating disease were associated with decreased motility. On multivariable analysis, hyper-enhancement, the presence of a comb sign, and global evidence of active inflammation remained associated with decreased motility. Of the factors suggesting complicated disease, the presence of stricture (Odds Ratio 0.40, 95% Confidence Interval 0.17-0.95, p-value 0.038) was associated with decreased motility.
Conclusions: As previously shown, well-established radiologic findings of bowel inflammation were associated with decreased small bowel motility. In this study, we have added that the radiologic finding of a fixed stricture is also associated with decreased motility.

1. Introduction

Cross sectional imaging enables insights into the pathologic state of the small intestine in patients with Crohn's disease (CD). Identifying sites and severity of intestinal inflammation provide the clinician with valuable information when considering symptom management, medication choices, and surgical options. Alerting clinicians to the presence of complications such as strictures, fistulae or abscesses often prompts a change in therapeutic strategy [1]. Recent studies demonstrate that cross sectional imaging findings may predict future disease complications such as abscess formation and obstruction [2,3]. Advances in cross sectional imaging have enabled increasingly important insights that can help identify patients who are at risk for complications guiding management and impacting interventions that could improve clinical outcomes.

Magnetic resonance enterography (MRE) has become increasingly used to evaluate the small bowel in CD patients due to its high sensitivity for bowel inflammation, multi-planar capability, and lack of radiation exposure [4,5]. The most recent American Gastroenterology Association (AGA) and American College of Gastroenterology (ACG) guidelines [6,7] consider MRE the preferred imaging modality for patients with Crohn's disease who are less than 50 years old or in patients who require serial imaging. Certain specialized sequences add significant information that aid in interpretation. Standard pulse sequences such as dynamic contrast-enhanced T1-weighted imaging and T2-weighted imaging help determine the presence of active inflammation and penetrating disease. Functional sequences, such as diffusion-weighting imaging, offer potential for assessment of disease activity. The cine sequence is a dynamic functional sequence that allows for characterization and quantification of small bowel motility [8,9].

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The cine sequence has been shown to increase lesion detection in CD when compared to static imaging alone related to its ability to assess functional bowel motility [10]. Bowel movement or motility can be affected in CD through several mechanisms including restriction of the mesentery, fat wrapping of the serosal surface, and fibrosis involving the bowel wall or serosa. Small bowel motility has been shown to be reduced in CD patients compared to healthy subjects [11]. Decreased motility as assessed by the cine sequence correlated with biomarkers of CD activity (C-reactive protein, calprotectin [12]), radiologic findings of inflammation [13,14], histopathology [15], and adhesion detection [16]. The cine sequence can facilitate diagnosis in otherwise equivocal cases [17]. To date, the cine sequence has been most closely associated with bowel inflammation although it has been used for other indications including evaluation of postoperative peristalsis [16] and medication effects [18]. Our aim was to confirm in our study population that intestinal inflammation was associated with decreased motility on the MRE cine sequence and determine if factors suggestive of complicated disease such as the presence of a stricture or fistula were associated with decreased motility. If so, this could add further relevance and significance to altered motility in patients with Crohn's disease.

2. Methods

This was a retrospective study. Subjects were identified with a search of the Integrated Data Repository using Informatics for Integrating Biology and the Bedside (i2b2), which is an NIH-funded National Center for Biomedical computing program (IRB201401008). Institutional review board (IRB) approval was obtained to evaluate the electronic medical record (EMR) of patients identified by the search. Included patients had Crohn's Disease with a small bowel lesion detected by MREs from March 2012 to December 2014, a biopsy-confirmed diagnosis of CD, cine sequence performed as part of the MRE, and at least one year of clinical outcomes data after the index scan. The population is enriched in Crohn's disease patients with complicated disease used in prior studies of disease complications and reflects our referral population. [2]

A total of 59 patients was included. EMRs were reviewed for all patients, and relevant data were collected for demographics, medical and surgical treatment history, duration of disease from onset to date of MRE, time since surgical intervention for CD if the patient had a history of surgery, body mass index (BMI), clinical disease activity (Harvey Bradshaw Index [HBI]) [19] and laboratory results (CRP). The HBI is collected on patients with CD at each clinic visit at our institution and recorded in the EMR. For those who did not have HBI scores collected from the clinic visit and there was sufficient information in the clinic progress note that was documented within proximity to the MRE (closest visit within one month) to calculate a score, an HBI score was calculated. Medication use for Crohn's disease (corticosteroids, immunomodulators, biologics), medications that could decrease motility (opioids, anti-diarrheals, anti-spasmolytics), and if the patient was receiving total parenteral nutrition (TPN) when the MRE was done were also documented. The extent of disease and perianal involvement was documented according to the Montreal classification for CD, which uses parameters of disease location, age of onset and disease behavior [20].

2.1. Imaging data capture

Two gastrointestinal radiologists used the standard MR images for orientation and to identify the small bowel lesion to be scored. The radiologists independently scored radiologic findings using a qualitative, subjective scoring system that has been used in a similar study [2] and modified based on a recently published consensus document [21]. Any score discordance of 2 points or greater was resolved by consensus between the radiologists. Individual elements of the radiologic findings score are discussed under the heading of "Structural MR Assessment" below. At a separate time (separated by at least two months) motility

Table 1
Standard MRE protocol.

T2 SS/HASTE with and without fat saturation[a]
T1 3D FSPGR (Fast Spoiled Gradient echo)[a,b]
LAVA (Liver Acquisition with Volume Acceleration)/VIBE (Volumetric Interpolated Breath-hold Examination)[a,b]
Cine two-dimensional (2D) steady state free precession (SSFP) FIESTA (Fast Imaging Employing Steady State Acquisition)/True FISP (Fast Imaging with Steady Precession)

MREs were performed on a 1.5 T GE Signa Gemsow (Harvey, IL), or on a 1.5 T Siemens Avanto or 3 T Siemens Verio (Erlangen, Germany).
[a] Axial and coronal.
[b] Before and after contrast.

was scored using a qualitative, subjective three-point scoring system for the cine sequence designed for our study that is based on scoring systems used in other published papers utilizing the cine sequence [10,16]. Individual elements of the motility score are discussed under the heading of "Motility Assessment" below. Radiologists remained blinded to the clinical outcomes of the patients. Both interpreting radiologists are board certified in diagnostic radiology and completed fellowships in abdominal imaging. One radiologist has thirteen years of interpretative experience in an academic practice, and the other has three years of experience in an academic practice.

2.2. MRE sequences

A standard MRE protocol was used for reviewing images (Table 1). MREs were performed on a 1.5 T GE Signa Gemsow (Harvey, IL), or on a 1.5 T Siemens Avanto or 3 T Siemens Verio (Erlangen, Germany). Axial and coronal T2 SS/HASTE with and without fat saturation sequences were performed after ingestion of 4 bottles of oral contrast (Volumen™) and intravenous injection of 1 mg glucagon (given after cine sequence performed). The protocol for oral contrast is to drink a total of 4 bottles (1.5 liters total) or the maximum that can be tolerated by the patient, divided over periods of 90 min, 60 min, 30 min, and 15 min before the scan starts. Axial and coronal T1 3D FSPGR (Fast Spoiled Gradient echo) LAVA (Liver Acquisition with Volume Acceleration)/VIBE (Volumetric Interpolated Breath-hold Examination) sequences were obtained before and after intravenous injection of an extracellular gadolinium-based contrast agent (dose 0.3 mL/kg; 2 mL/sec). Timing of breath-hold varied depending on patient tolerance and therefore could not be standardized for uniformity. Axial diffusion-weighted images and coronal cine two-dimensional (2D) steady state free precession (SSFP) FIESTA (Fast Imaging Employing Steady State Acquisition)/True FISP (Fast Imaging with Steady Precession) sequences were performed. For the cine sequence, 400–500 images were obtained at 15 temporal locations, each containing approximately 25 phases and a series acquisition time of approximately 4 min. The cine temporal resolution was 1 s per image and the flip angle ranged from 45 degrees to 70 degrees, depending on the MR system [5]. Imaging parameters are listed in Table 2. Cine sequence is the first diagnostic

Table 2
MRE Imaging Parameters.

|	
Temporal resolution	1 image/second
Scan duration	total of 400–500 images over 15 temporal positions
Bowel prep	oral contrast
Breath hold	yes
Slice thickness	7 mm
Slice gap	0 mm
Volume coverage	480 mm
Imaging plane	coronal

MREs were performed on a 1.5 T GE Signa Gemsow (Harvey, IL) or on a 1.5 T Siemens Avanto or 3 T Siemens Verio (Erlangen, Germany). A range of parameters was noted to account for scan-to-scan variability.

Fig. 1. 61 year old male status post ileocececectomy with stricture (arrow) and upstream bowel dilatation. The real-time cine sequence showed decreased motility of the small bowel at the level of the stricture.
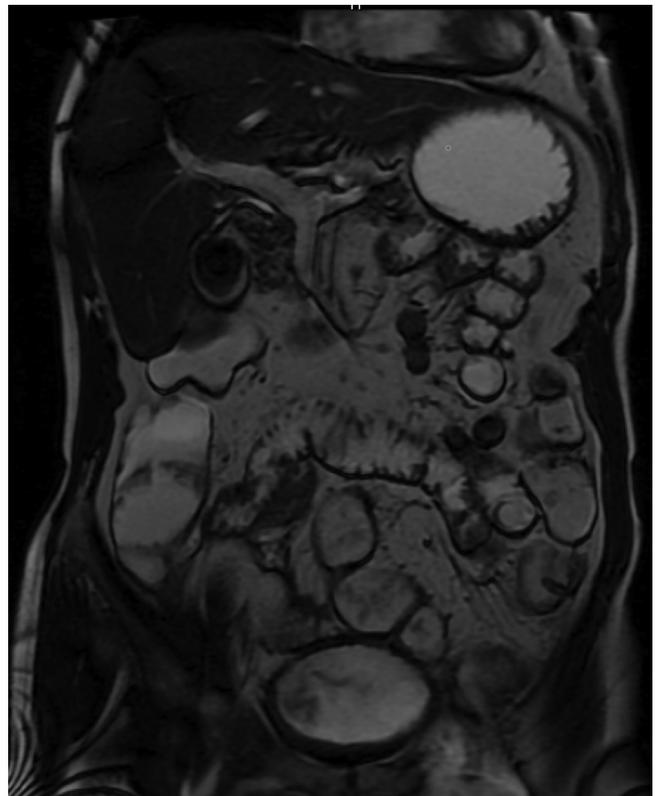
Fig. 3. 76 year old male with normal motility on cine sequence, no active inflammation and no stricture.
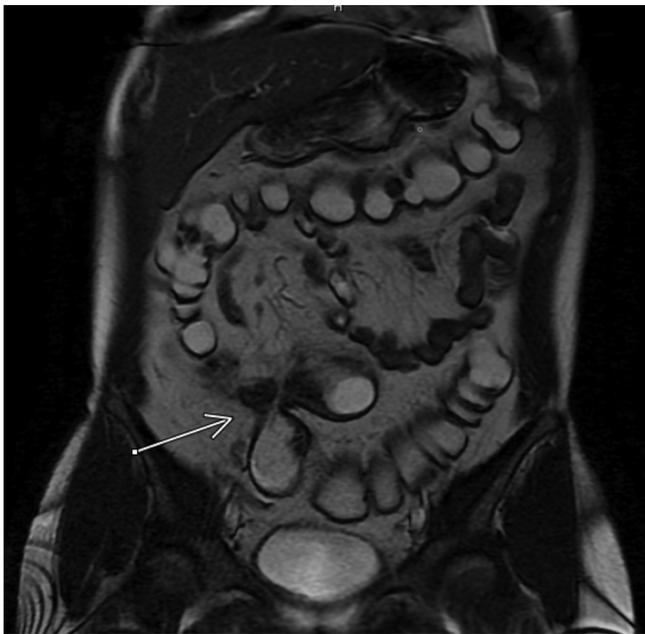
Fig. 2. 41 year old female with interloop fistula between the terminal ileum, cecum and sigmoid (arrow). There was no motility of these affected bowel loops on the cine sequence.

sequence performed immediately after the acquisition of the localizer images (Figs. 1–3).

2.3. Structural MR assessment

Sixty-three small bowel lesions detected on MRE from patients with Crohn's disease were included and scored independently. Four patients had two lesions, which were independently scored for radiologic

findings and cine sequence on a single scan. A standardized score sheet that was adapted from prior published studies [2] was used to capture the length of the lesion (in centimeters), degree of enhancement, thickness of the small bowel lesion (in millimeters), presence of peri-enteric fluid, comb sign (hypervascularity adjacent to bowel associated with active inflammation), fixed stricture, minimal lumen diameter (in millimeters) and cine sequence score. The presence of peri-enteric fluid and the presence of a fistula were considered categorical variables as described in Table 3. Thickness was scored as mild (3–5 mm), moderate (6–9 mm) or severe (≥ 10 mm). The "global assessment of active inflammation" was included to provide for a radiologist's informed opinion on whether the segment appeared inflamed. This was included in case there were intangible factors that the individual elements were not capturing. We defined this as any global evidence of active inflammation, including the presence of mural edema associated with segmental mural hyper-enhancement, particularly when asymmetric, and wall thickening. A fixed stricture was defined as a fixed point of stenosis lasting for the entire duration of the imaging study associated with abnormal wall thickening. This was to differentiate it from the transient luminal narrowing resulting from peristalsis. Stenosis was associated with a T2 signal abnormality (either hyperintense or hypointense). Strictures were scored as 0 if not present, and stratified as mild (no upstream bowel dilatation; score = 1), moderate (upstream dilatation between 2 and 4 cm in caliber; score = 2), and severe (upstream ductal dilatation exceeding 4 cm in caliber; score = 3). The smallest diameter was recorded in millimeters as the minimal lumen dimension. For purposes of analysis, penetrating disease was defined as a sinus tract, fistula, or peri-enteric fluid associated with the diseased loop of bowel. All findings of penetrating disease in this study involved the actual lesion(s) of interest, i.e. a fistula was present at the area of bowel wall thickening/luminal narrowing. Radiology scoring parameters for small bowel lesions on MRE are presented in Table 3.

Table 3

Radiology Scoring Parameters for Small Bowel Lesions.

	0	1	2	3	4
Continuous variables					
Thickness of lesion, mm (score 1-3)	–	3-5 (mild)	6-9 (moderate)	≥10 (severe)	–
Enhancement (score 0-4)	None	Equivocal	Mild	Moderate (renal cortex)	Severe (vessel)
Comb's sign (score 0-4)	None	Equivocal	Mild	Moderate	Severe
Stricture/luminal narrowing (score 0-3)	None	Yes, no proximal dilatation	Yes, proximal dilatation < 4 cm	Proximal dilatation > 4 cm	–
Categorical variables					
Cine sequence (score 0-2)	Peristalsis/no motility	Reduced motility	Normal motility	–	–
Global assessment of active inflammation (score 0/1)	None	Yes	–	–	–
Peri-enteric fluid (0/1)	None	Yes	–	–	–
Presence of fistula (score 0/1)	None	Yes	–	–	–

Note: Parameters including thickness of lesion, enhancement, comb sign, stricture/luminal narrowing, were determined using standard MR images and were scored as indicated and considered continuous variables. Length of the lesion and minimum luminal diameter were continuous and measured in centimeters and millimeters, respectively. The cine sequence, global assessment of active inflammation, peri-enteric fluid and presence of fistula were considered categorical variables. Peri-enteric fluid was considered a categorical variable and was scored as 0 if no peri-enteric fluid and 1 if either mesenteric edema, inflammatory mass or abscess. Similarly, a fistula was scored as 0 if not present and 1 if an enteroenteric, enterovesical or enterocutaneous fistula were present. The number of patients with each type of peri-enteric fluid or fistula are described in the text. Additional details of scoring are provided in the Methods section.

2.4. Motility assessment

For the cine sequence scoring, the radiologists reviewed the sequences on a picture archiving and communication system (Visage Imaging, San Diego, CA) using the default frame rate. The cine sequence was scored based on the motility in the small bowel segment in which the small bowel lesion of interest(i.e. the segment with wall thickening with or without active inflammation) was located and the motility in this region was scored relative to the overall bowel motility whether or not there was upstream bowel dilation. For the purposes of this study, "normal bowel" motility was defined as no difference in motility of the diseased segment compared to the non-diseased bowel. The scoring was done qualitatively, with 0 = no motility/peristalsis (complete absence of wall motion), 1 = reduced motility (diminished wall motion compared to non-diseased bowel loops) and 2 = normal motility (rhythmic motion of small bowel with regularly alternating contractions and dilatations) when the abnormal segment is compared to the rest of the abdomen [10].

2.5. Statistical analysis

Descriptive analysis for categorical variables was done using proportions. For continuous variables, the range, median, means and their standard deviations were estimated. The variables in which ascending scores corresponded with increasing intensity or severity of the variable were considered as continuous for the purposes of this analysis. The non-parametric Kruskal-Wallis equality of proportion rank test was used to estimate descriptive associations between a continuous variable (age and BMI) against the three categorical levels of the cine sequence (0, 1, 2) as well as using the univariate ordinal regression model.

Two analyses were done. The univariate ordered logistic regression analysis includes multiple radiologic findings, clinical factors and laboratory values that are potentially associated with complicated disease (Table 5). Factors that were associated with inflammation, including length of the lesion, global assessment of active inflammation, thickness, hyper-enhancement, comb sign as well as CRP, were included. A multivariable ordered logistic regression analysis was then fitted to model the radiologic findings and adjusted for the possible confounders that were clinically important and significant on univariate analysis. Results are presented in Tables 5 and 6. Data were analyzed using the Stata Statistical Software: Release 15. The significance level was set to p-value 0.05.

3. Results

Demographics are presented in Table 4. The kappa statistic calculated from the first ten scores in the radiologic score data set and was 0.88 and the agreement between radiologists for scoring the cine sequences was 100%. Complicated Crohn's disease defined as the cross sectional imaging presence of a stricture, fistula or peri-enteric fluid were present in 86% of cases. Of the lesions associated with a stricture, the minimum luminal diameter was between 1.5 mm and 8 mm. 56% had peri-enteric fluid present on the scan. Of these, 80% had mesenteric edema, 14% had inflammatory mass and 6% had an abscess. Of lesions associated with a fistula, 64% had an enteroenteric, 0% had an enterovesical and 36% had an enterocutaneous fistula. Decreased or absent motility was present in 90% of cases.

Unviariate analysis was performed to identify relevant factors associated with decreased or absent motility. On univariate analysis, multiple cross sectional imaging radiologic findings were associated with decreased motility including length of the lesion (in centimeters),

Table 4

Demographics and Descriptive Data.

Patient population	Number of Patients (%)	
Gender		
Female	42 (71.2)	
Male	17 (28.8)	
Race		
Caucasian	52 (89.7)	
African American and other	6 (10.3)	
Medications		
Corticosteroids	28 (48%)	
Biologics	24 (41%)	
Immunomodulators	14 (24%)	
Biologics or immunomodulators	33 (59%)	
Opioids, anti-diarrheals, anti-spasmolytics	18 (31%)	
Total parenteral nutrition (TPN)	4 (7%)	
History of small bowel surgery	26 (45%)	
Patient characteristics	**Mean ± SD**	**Range**
Age (Year)	40.8 ± 16.1	19-88
BMI (Body Mass Index, kg/m²)	25.1 ± 5.5	17.3-40.9
Disease characteristics	**Mean ± SD**	**Range**
Average disease duration (months)	165.2 ± 157.7	0-68
Time since most recent surgery (months)	138.2 ± 135.1	1-576
Laboratory results	**Mean ± SD**	**Range**
HBI (Harvey Bradshaw Index)	8 ± 8.8	0-57
CRP (C-reactive Protein)	27.2 ± 35.5	0.8-133.2

Table 5
Univariate analysis.

Variable	OR	SE	P-value	95% CI
Radiologic:				
Length of the lesion	0.88	0.050	**0.029**	0.79 - 0.99
Global evidence of active inflammation	0.08	0.055	**< 0.001**	0.02 - 0.30
Thickness	0.37	0.186	**0.048**	0.14 - 0.99
Enhancement	0.34	0.126	**0.004**	0.16 - 0.70
Comb sign	0.56	0.126	**0.011**	0.36 - 0.88
Peri-enteric fluid	0.31	0.159	**0.022**	0.11 - 0.85
Presence of fistula	0.29	0.172	**0.037**	0.09 - 0.93
Stricture	0.55	0.156	**0.036**	0.32 - 0.96
Lumen diameter	0.86	0.158	0.406	0.60 - 1.23
Patient demographics:				
Age	1.06	0.156	0.319	0.96 - 1.05
Gender	1.43	0.702	0.462	0.55 - 3.74
Race	0.92	0.783	0.925	0.18 - 4.86
BMI	1.07	0.064	0.279	0.95 - 1.20
Clinical/Laboratory data:				
HBI	1.12	0.032	**< 0.001**	1.06 - 1.18
Montreal classification	0.90	0.254	0.711	0.52 - 1.57
Disease duration	1.00	0.000	0.210	1.00
CRP	0.99	0.011	0.428	0.97 - 1.01
Medication/TPN:				
Corticosteroids	3.55	1.908	**0.018**	1.24 - 10.2
Biologic	0.45	0.233	0.123	0.17 - 1.24
Immunomodulator	1.34	0.766	0.609	0.44 - 4.11
Biologic/Immunomodulator	0.79	0.396	0.634	0.29 - 2.11
Opioids, anti-diarrheals, anti-spasmolytics	2.70	1.436	0.063	0.95 - 7.66
TPN	2.32	5.350	0.716	0.02 - 214.5
Surgery:				
History of surgery	0.88	0.439	0.802	0.33 - 2.3
Time since most recent surgery	1.00	0.000	0.953	1.00

Bold values indicate statistically significant P-values (P-value < 0.05).

Table 6
Multivariable analysis.

Variable	OR	SE	P-value	95% CI
Peri-enteric fluid	3.28	2.747	0.156	0.64 - 16.9
Presence of fistula	0.16	0.178	0.097	0.02 - 1.38
Stricture	0.40	0.177	**0.038**	0.17 - 0.95
HBI	1.06	0.043	0.163	0.98 - 1.15
Corticosteroids	15.51	14.830	**0.004**	2.38 - 101.1
Length of lesion	1.01	0.105	0.960	0.82 - 1.23
Enhancement	0.44	0.173	**0.038**	0.21 - 0.95
Thickness	2.53	1.853	0.206	0.60 - 10.6
Comb Sign	0.42	0.130	**0.005**	0.23 - 0.77
Global assessment of Active Inflammation	0.17	0.147	**0.039**	0.03 - 0.91

Bold values indicate statistically significant P-values (P-value < 0.05).

degree of enhancement, thickness of the small bowel lesion (in milli-meters), presence of comb sign (hypervascularity adjacent to bowel associated with active inflammation) (Table 5). Findings suggestive of complicated disease including the presence of peri-enteric fluid (me-senteric edema, inflammatory mass and abscess considered together), a fistula (enteroenteric, enterovesical, enterocutaneous) or a fixed stric-ture were also associated with decreased motility (Table 5). Patient characteristics such as age, gender, race, and BMI were not associated with decreased motility (Table 5). Additionally, clinical disease classi-fication (Montreal classification), disease duration and CRP were not associated with decreased motility. Somewhat surprisingly, a high clinical disease severity index (HBI) and corticosteroid use were asso-ciated with decreased odds of decreased motility (increased odds of normal motility). Biologics, immunomodulators, opioids, anti-diar-rheals, anti-spasmolytics and TPN were not associated with decreased motility. History of CD-related surgical intervention was not associated with decreased motility (OR 0.88, 95% CI 0.33–2.3, p-value 0.802), and

this did not change with length of time since surgery (OR 1.00, 95% CI 1.00, p-value 0.953).

On multivariable analysis, the presence of a stricture (OR 0.40, 95% CI 0.17-0.95, p-value 0.038) was significantly associated with de-creased small bowel motility. The presence of a fistula was not asso-ciated (OR 0.16, 95% CI 0.02–1.38, p-value 0.097) with decreased motility. Additionally, when adjusting for several radiologic findings associated with inflammation in the multivariable model, hyper-en-hancement (OR 0.44, 95% CI 0.21-0.05, p-value 0.038), presence of a comb sign (OR 0.42, 95% CI 0.23-0.77, p-value 0.005) and global evidence of active inflammation (OR 0.17, 95% CI 0.03-0.91, p-value 0.039) remained significant. On multivariable analysis, there was no significant association between the length of the lesion or thickness of the lesion and cine sequence. Finally, when adjusting for HBI and use of corticosteroids, only corticosteroids (OR 15.51, 95% CI 2.38–101.1, p-value 0.004) remained significant and associated with normal small bowel motility (Table 6).

4. Discussion

Cross sectional imaging has improved our ability to detect intestinal inflammation and identify complications of Crohn's disease. Patients with complicated Crohn's disease have fistulae and strictures that can result in devastating clinical outcomes of abscess and obstruction that often require surgery and complicate medical therapy. While in-flammation is identified with high accuracy on routinely performed cross sectional imaging, findings of stricture and fistula are less con-sistently identified and reported [22]. Special MR sequences such as the cine sequence improves the diagnostic accuracy of Crohn's disease [5,20], and cine findings have been shown to be associated with in-testinal inflammation [12,15]. Our results confirm prior studies de-monstrating that MRI findings of bowel inflammation are associated with decreased motility as determined by the cine sequence. Our data demonstrate that radiologic evidence of a fixed small bowel stricture is also associated with decreased motility. The cine sequence may add value to standard T1- and T2-weighted images for articulation of radiologic CD findings.

Previous work has shown that the cine sequence correlates with degree of inflammation and length of inflammation in the diseased small bowel segment on imaging [23], and with evidence of in-flammation on histopathology of the terminal ileum [15]. In our data, the cine sequence was associated with multiple findings of inflamma-tion, including hyperenhancement, increased wall thickness and comb sign (associated with active or past inflammation). In our study, there was an association between corticosteroid use and normal motility. Radiologic findings in patients on corticosteroids, a potent anti-in-flammatory, could be inferred as a measure of post-therapy changes on MRE, which are increasingly used to gauge clinical response [24].

One of the unexpected results in our study was an association be-tween motility and HBI, a common Crohn's disease activity index, such that a high score indicative of more severe symptoms was associated with normal motility. One might expect more severe disease to display restricted or less motility. Prior studies have also shown poor correla-tion between symptom-based scoring of active CD and objective mea-sures of disease severity and behavior (inflammatory, penetrating, or stricturing) [25]. This is thought to be because of the subjective nature of the patient-centered questions regarding abdominal pain and diar-rhea severity. In our study, the odds ratios were striking for patients with severe disease by HBI, but the significance was not seen on mul-tivariable analysis. It is also possible that other more sophisticated motility patterns could be contributing that were not analyzed in our study. Finally, it is possible that the finding may be a result of type I error in the univariate analysis.

When bowel narrowing on MRE is identified, clinicians would like to know whether the narrowing is predominantly inflammatory or fi-brotic as this determines whether the treatment is usually medical or

surgical, respectively [21]. Diagnosing fibrosis, which is not directly identified on MRE, based on the lack of inflammatory findings in an involved bowel segment is discouraged [21]. However, an overlap can exist in the disease phenotypes given that active inflammation is usually present in strictures [26]. Radiologists can use multiple radiologic findings, including degree of inflammation, presence of stricture with additional information about its length and degree of upstream dilatation and presence of fistula to inform their assessment of relative inflammatory and fibrotic state of tissue [27]. Repeated MRE especially with evidence of transmural healing following therapy strongly inform disease assessment [28,29]. The cine sequence is easy to add to standard MRE protocols as it does not require any additional preparation, requires little additional amount of time, and it is relatively simple to interpret qualitatively by radiologists with good inter-reader consensus [30].

Our study has several limitations. First, the study design is retrospective with its inherent limitations [31]. Second, we defined "normal" motility as no change in motility of the diseased segment compared to the rest of the bowel, as has been defined in similar studies [10,30]. It is difficult to truly define "normal" small bowel motility. In our study, we assigned a motility score for small bowel lesions relative to the overall bowel motility on a per-subject basis. In a related limitation, we assessed motility of small bowel lesions in relation to global motility of other small bowel loops. We focused solely on scoring of the lesion of interest, not taking into account motility of upstream or downstream segments of small bowel. For example, our study would not allow assessment of hypermotility that can occur above a narrowed segment [10]. In our study, we did not observe a tangible increase in small bowel motility relative to a patient's overall bowel motility. An additional point about motility scoring, for simplicity and reproducibility in routine clinical practice, we elected to use a three-point qualitative scoring system; we acknowledge that more quantitative techniques, particularly utilizing dedicated software, would potentially create more robust data. This could be explored in a future study. Next, the volume of ingested oral contrast can affect small bowel motility; we were not able to control for this, as some patients may not tolerate the full-prescribed volume of contrast. Additionally, our study's sample size is relatively small, especially in the cine = 2 category, which consists of small bowel lesions that demonstrate motility similar to the remainder of the subject's small bowel. Finally, four subjects had two lesions scored and included in our data set. In each case, each lesion was located in a different region of the small bowel offset by enough distance that overlap was of minimal concern.

In conclusion, the cine sequence can be a helpful tool for increasing lesion detection and facilitating diagnosis in CD. As previously shown, decreased small bowel motility was associated with well-established radiologic findings of bowel inflammation. In this study, we have added the important finding that the radiologic finding of a fixed small bowel stricture is also associated with decreased motility. This information can be valuable to both the radiologist and gastroenterologist.

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Declaration of Competing Interest

None.

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