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Inter-radiologist agreement using Society of Abdominal Radiology-American Gastroenterological Association (SAR-AGA) consensus nomenclature for reporting CT and MR enterography in children and young adults with small bowel Crohn disease

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Abstract

Purpose: To assess inter-radiologist agreement using the Society of Abdominal Radiology-American Gastroenterological Association (SAR-AGA) consensus recommendations for reporting CT/MR enterography exams in pediatric and young adult small bowel Crohn disease (CD).
Methods: Institutional review board approval was obtained for this HIPAA-compliant retrospective investigation; the requirement for informed consent was waived. 25 CT and 25 MR enterography exams performed in children and young adults (age range: 6–23 years) between January 2015 and April 2017 with a distribution of ileal CD severity (phenotype) were identified: normal or chronic CD without active inflammation (40%), active inflammatory CD (20%), stricturing CD (20%), and penetrating CD (20%). Five fellowship-trained pediatric radiologists, blinded to one another, documented key imaging findings and standardized impressions based on SAR-AGA consensus recommendations. Inter-radiologist agreement was evaluated using Fleiss' multi-rater kappa statistic (κ) with 95% confidence intervals (CI).
Results: Inter-radiologist agreement was moderate for all key imaging findings except presence of ulcerations (κ 0.37 [95% CI 0.28–0.46]) and sacculations (κ 0.31 [95% CI 0.23–0.40]). Agreement for standardized impressions was substantial for stricturing disease (κ 0.79 [95% CI 0.70–0.87]) and moderate for presence of inflammation (κ 0.49 [95% CI 0.44–0.56]) and penetrating disease (κ 0.58 [95% CI 0.49–0.67]). No significant difference in agreement was found between CT and MRI.
Conclusions: Agreement among five pediatric radiologists was moderate to substantial for SAR-AGA standardized impressions and fair to moderate for key imaging findings of pediatric and young adult CD.

Key words: Inflammatory bowel disease—Crohn disease—Enterography—Pediatric—Standardized reporting—Inter-reader agreement

CT and MR enterography play an increasingly important role in the management of Crohn disease in adults and children [1–3]. These non-invasive imaging studies are required at initial diagnosis and routinely aid in monitoring for disease progression and complications and in evaluation of treatment response. Enterography complements endoscopic evaluation by offering a means to evaluate intramural and extra-enteric disease that

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cannot be assessed by an intraluminal endoscope and to assess for small bowel disease involving the jejunum or proximal ileum that is inaccessible by conventional endoscopy [4–6]. Enterography correlates well with the endoscopic and histologic evaluation of disease activity, and it has been shown to affect clinical management and correlate with clinical disease course [1, 7–11].

The Society of Abdominal Radiology (SAR) Crohn Disease-Focused Panel recently partnered with the American Gastroenterological Association (AGA) to develop consensus recommendations for the utilization, interpretation, and reporting of CT and MR enterography in children and adults with small bowel Crohn disease [12]. This effort, which gained approval from other societies including the Society for Pediatric Radiology, proposes a standard system for interpreting and reporting CT and MR enterography exams that includes key imaging findings that should be reported, standardized terminology for describing such findings, and standardized impressions for conveying the overall state of disease severity to referring physicians and other treating clinicians. The authors indicate that a primary goal of their document is to improve clinical care by facilitating communication between radiologists, gastroenterologists, and surgeons.

This effort is part of a larger movement in the radiology community to improve the clinical utility of radiology reports through organized report structure and a standard lexicon [13–17]. Proposed benefits of structured reporting in the radiology literature include reduced error rates, more frequent documentation of pertinent positive and negative findings, and facilitation of data mining for research, quality assurance endeavors, or reimbursement [18–21]. Further, multiple studies have shown a preference for structured reports from the perspective of the referring physician [18, 19, 22].

The SAR-AGA reporting recommendations could serve as an important tool for translating complex medical images into succinct, actionable clinical information. The success of this effort will, in part, depend on agreement among radiologists when utilizing the recommended reporting terms and structure. The purpose of our study was to assess inter-reader agreement when using the newly devised SAR-AGA consensus recommendations as a framework for interpreting and reporting CT and MR enterography in children and young adults with small bowel Crohn disease.

Methods

This inter-observer agreement study was approved by our institutional review board with a waiver of informed consent, and it was conducted in a manner that was compliant with the Health Insurance Portability and Accountability Act (HIPAA, USA) of 1996.

Study population

A single investigator (M.A.R.) reviewed imaging reports for all pediatric and young adult (age range: 2-25 years) patients who underwent either CT or MR enterography at (Cincinnati Children's Hospital Medical Center) between January 1, 2015, and April 30, 2017. 25 CT enterography and 25 MR enterography exams from 50 unique subjects with a clinical diagnosis of ileal Crohn disease were selected. The clinical diagnosis was made in most cases by endoscopic biopsy, while a minority of cases was confirmed by surgery. Exams from patients without a diagnosis of Crohn disease, with Crohn disease not involving the ileum, or with recent bowel surgery (within 3 months) were excluded. Patients with ileal disease were specifically selected to avoid disagreement between reviewers resulting from review of disparate bowel segments. All exams were of diagnostic image quality, as judged by the reviewing investigator. Based on the original imaging report, exams were selected to represent the spectrum of disease states (phenotypes): (1) normal imaging appearance of the small bowel (ileum) or chronic ileal changes of Crohn disease but no active inflammation, (2) active inflammatory disease of the ileum without stricturing or penetrating disease, (3) stricturing disease of the ileum (defined by the consensus document as luminal small bowel narrowing with ≥ 3 cm upstream dilation), and (4) penetrating disease of the ileum (e.g., sinus tract, fistula, abscess, inflammatory mass, or some combination). We targeted a case mix of 40% normal or chronic Crohn disease, 20% active inflammatory disease, 20% stricturing disease, and 20% penetrating disease. Consecutive cases for each category were added to the final study population in chronological order (beginning with exams performed on January 1, 2015) until the desired case mix was achieved, with the exception that no individual patient was included in the final study population more than once.

Imaging protocols

All CT enterography examinations had been performed on 64- or 320-detector row CT scanners (Aquilion and Aquilion One CT scanners; Toshiba America Medical Systems, Tustin, CA). Images were obtained in the enteric phase following the intravenous injection of ioversol low-osmolality contrast material (2 mL/kg, up to 100 mL maximum volume; injection rate of 2 mL/s). The following series were available to study readers: axial 0.5 mm, axial 3 mm, and coronal 3 mm.

MR enterography examinations had been performed on 1.5 or 3 Tesla MRI scanners (Philips Healthcare, Best, the Netherlands; and GE Healthcare, Waukesha, WI). All MR enterography examinations included unenhanced single-shot fast spin-echo sequences in the axial

and coronal planes without and with fat-saturation, axial diffusion-weighted imaging, and coronal and axial post-contrast imaging using a 3D T1-weighted gradient recalled echo sequence. Gadoterate meglumine gadolinium-based contrast material was injected using a standardized weight-based approach (0.1 mmol/kg, up to 20 mL maximum volume). Glucagon was administered to all MR enterography patients using a split-bolus approach (0.3 mg subcutaneous injection at the beginning of the exam, and 0.3 mg intravenous injection prior to contrast-enhanced imaging).

Both CT and MR enterography patients received a weight-based oral prep (20 mL/kg, up to 1350 mL) of a neutral barium-containing contrast material (VoLumen; Bracco Diagnostics, Milan, Italy) in order to distend the bowel and aid the detection of mucosal and bowel wall post-contrast hyperenhancement. One patient was unable to tolerate the oral prep and instead drank an equivalent volume of water.

Radiologist image review

Five fellowship-trained, board-certified, pediatric radiologists (J.D., C.A., M.S.R., A.J.T., A.T.T.) with five to 19 years of post-fellowship experience and focused practice in abdominal imaging, including experience interpreting CT and MR enterography, reviewed the selected cases. Using the SAR-AGA consensus recommendations for interpretation and reporting of CT and MR enterography exams in the setting of small bowel Crohn disease, we developed a case report form (Appendix) for structured review of each study, which was provided to each reader prior to commencing study review. An illustrated guide, demonstrating key imaging findings with example images originating from the consensus document and supplemented by cases from our own institutional imaging archive, accompanied the case report form. We also provided specific descriptions of each type of penetrating disease, adapted from the SAR-AGA consensus document (Table 1), and provided definitions for the standardized impression statements. No other formal training was provided, as we hoped to establish a baseline level of agreement among radiologists after an initial introduction to the consensus document, similar to what practicing radiologists might receive.

After a 1-week period to allow study radiologists to review the illustrated guide and familiarize themselves with the case report form and relevant terminology, we provided each reader access to the selected 25 CT and 25 MR enterography exams, which were anonymized in our research picture and archiving communication system (PACS). Each study was given a unique identifier for each individual reader, and studies were randomized differently for each reader. Readers were blinded to the original clinical interpretations and to the results of the other readers. Readers were instructed only to review the distal/terminal ileum in order to isolate variability to the application of the interpretive criteria rather than the identification of diseased segments. Studies were reviewed over a period of 2 weeks. Study data were collected and managed using REDCap (Research Electronic Data Capture) electronic data capture tools hosted at (Cincinnati Children's Hospital Medical Center) [23].

Statistical analysis

All statistical analyses were performed using SAS, version 9.3 (SAS Institute, Inc., Cary, NC). Continuous data were summarized as means and standard deviations, while categorical data were summarized as counts and percentages. Inter-reader agreement between all five radiologists as a single group was calculated for each item on the case report form using Fleiss' multi-rater kappa statistic (κ). Ninety-five percent confidence intervals (CI) also were calculated. Levels of inter-reader agreement were interpreted using categories devised by Landis and Koch [24], with a κ less than 0 considered poor agreement, 0.01–0.20 considered slight agreement, 0.21–0.40 considered fair agreement, 0.41–0.60 considered moderate agreement, 0.61–0.80 considered substantial agreement, and 0.81–1 considered almost perfect agreement.

Results

The final study population included 32 male and 18 female subjects. The mean age of the study population was 15.2 years (range, 6.3–23.0 years). The CT enterography group included 14 male and 11 female subjects with a mean age of 14.3 years (range, 6.3–23.0 years), and the MR enterography group included 18 male and 7 female subjects with a mean age of 16.1 years (range, 11.2–22.3 years).

Inter-reader agreement

Inter-reader agreement was fair to moderate for key imaging findings and moderate to substantial for standardized impression statements (Table 2). Agreement was moderate for the majority of key imaging findings but only fair for: presence of ulcerations (κ 0.37 [95% CI 0.28–0.46]) and presence of sacculations (κ 0.33 [95% CI 0.24–0.42]). Inter-reader agreement was substantial for the standardized impression statement describing stricturing disease (κ 0.79 [95% CI 0.70–0.87]), and moderate for the other impression statements.

Table 3 lists the frequency at which four or more of the five study readers were in agreement for each of the key imaging findings and standardized impression statements. The frequency at which four or more readers agreed on key imaging findings ranged from 27 of 50

Table 1. Types of penetrating disease

Penetrating disease type	Description
Simple fistula	Extra-enteric tract connecting bowel to another structure
Complex fistula	Multiple extra-enteric tracts connecting bowel to multiple structures; often has an ''asterisk'', ''clover'', or ''star'' shape
Sinus tract	Bowel wall defect that extends beyond the bowel wall but does not connect to another structure
Inflammatory mass	Ill-defined, mass-like, inflammatory process consisting of mixed fat and/or soft tissue attenuation/signal intensity
Abscess	Perienteric fluid collection with rim enhancement and/or internal air

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Table 2. Overall and modality-specific inter-reader agreement

	Overall group (CT and MRI)		CT only		MRI only	
	Kappa (95% CI)	*p* value	Kappa (95% CI)	*p* value	Kappa (95% CI)	*p* value
Impression statements						
Inflammation statement	0.50 (0.44–0.56)	< 0.0001	0.43 (0.34–0.52)	< 0.0001	0.56 (0.47–0.65)	< 0.0001
Stricture statement	0.79 (0.70–0.87)	< 0.0001	0.94 (0.25–1.00)	< 0.0001	0.66 (0.54–0.78)	< 0.0001
Penetrating disease statement	0.58 (0.49–0.67)	< 0.0001	0.61 (0.49–0.73)	< 0.0001	0.54 (0.42–0.66)	< 0.0001
Key imaging findings						
Segmental mural hyperenhancement	0.41 (0.36–0.46)	< 0.0001	0.34 (0.27–0.41)	< 0.0001	0.44 (0.36–0.51)	< 0.0001
Bowel wall thickness	0.41 (0.35–0.47)	< 0.0001	0.35 (0.27–0.43)	< 0.0001	0.46 (0.37–0.55)	< 0.0001
Intramural edema (MRI only)	0.47 (0.34–0.59)	< 0.0001	–	–	0.47 (0.34–0.59)	< 0.0001
Stricture	0.59 (0.52–0.65)	< 0.0001	0.66 (0.57–0.76)	< 0.0001	0.51 (0.42–0.60)	< 0.0001
Ulcerations	0.37 (0.28–0.46)	< 0.0001	0.39 (0.27–0.52)	< 0.0001	0.34 (0.22–0.47)	< 0.0001
Sacculations	0.33 (0.24–0.42)	< 0.0001	0.28 (0.15–0.41)	< 0.0001	0.38 (0.26–0.51)	< 0.0001
Presence of penetrating disease	0.60 (0.51–0.68)	< 0.0001	0.61 (0.49–0.73)	< 0.0001	0.56 (0.44–0.69)	< 0.0001
Type of penetrating disease	0.25 (0.13–0.38)	< 0.0001	0.38 (0.14–0.63)	0.0009	0.17 (0.02–0.32)	0.0132
Engorged vasa recta	0.59 (0.50–0.68)	< 0.0001	0.69 (0.57–0.82)	< 0.0001	0.47 (0.35–0.60)	< 0.0001
Perianal disease	0.43 (0.34–0.52)	< 0.0001	0.40 (0.27–0.52)	< 0.0001	0.42 (0.29–0.54)	< 0.0001

Kappa values are for the entire group of readers ($n = 5$)
CI Confidence interval

Table 3. Key imaging findings and impression statements with at least four of five readers in agreement

	Overall group (CT and MRI)		CT only		MRI only	
	All readers agree N/D (%)	≥ 4 readers agree N/D (%)	All readers agree N/D (%)	≥ 4 readers agree N/D (%)	All readers agree N/D (%)	≥ 4 readers agree N/D (%)
Impression statements						
Inflammation statement	24/50 (48%)	35/50 (70%)	11/25 (44%)	16/25 (64%)	13/25 (52%)	19/25 (76%)
Stricture statement	45/50 (90%)	48/50 (96%)	24/25 (96%)	25/25 (100%)	21/25 (84%)	23/25 (92%)
Penetrating disease statement	30/50 (60%)	46/50 (92%)	17/25 (68%)	24/25 (96%)	13/25 (52%)	22/25 (88%)
Key imaging findings						
Segmental mural hyperenhancement	12/50 (24%)	27/50 (54%)	5/25 (25%)	13/25 (52%)	7/25 (28%)	14/25 (56%)
Bowel wall thickness	15/50 (30%)	28/50 (56%)	6/25 (24%)	14/25 (56%)	9/25 (36%)	14/25 (56%)
Intramural edema (MRI only)	10/25 (40%)	20/25 (80%)	–	–	10/25 (40%)	20/25 (80%)
Stricture	21/50 (42%)	42/50 (84%)	13/25 (52%)	22/25 (88%)	8/25 (32%)	20/25 (80%)
Ulcerations	19/50 (38%)	33/50 (66%)	10/25 (40%)	17/25 (68%)	9/25 (36%)	16/25 (64%)
Sacculations	30/50 (60%)	43/50 (86%)	13/25 (52%)	21/25 (84%)	17/25 (68%)	22/25 (88%)
Presence of penetrating disease	30/50 (60%)	47/50 (94%)	17/25 (68%)	24/25 (96%)	13/25 (52%)	23/25 (92%)
Type of penetrating disease	1/15 (7%)	5/15 (33%)	1/5 (20%)	2/5 (40%)	0/10 (0%)	3/10 (30%)
Engorged vasa recta	29/50 (58%)	44/50 (88%)	18/25 (72%)	23/25 (92%)	11/25 (44%)	21/25 (84%)
Perianal disease	31/50 (62%)	44/50 (88%)	19/25 (76%)	25/25 (100%)	12/25 (48%)	19/25 (76%)

N/*D* Numerator/denominator

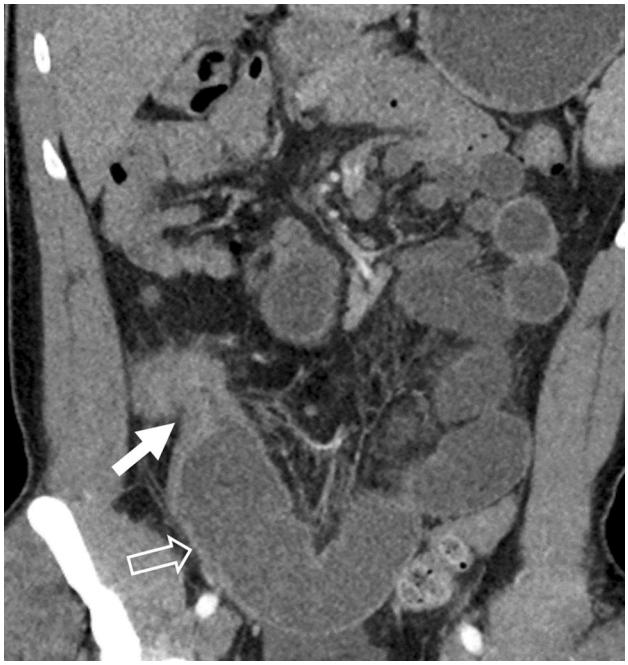

Fig. 1. Coronal post-contrast CT enterography image illustrating stricturing disease, which is defined by the Society of Abdominal Radiology-American Gastroenterological Association (SAR-AGA) consensus recommendations as an area of luminal narrowing with unequivocal upstream dilation measuring ≥ 3 cm in caliber. This image shows an area of narrowed terminal ileum (solid arrow) with a thickened, enhancing wall and inflammation of the surrounding fat. The upstream bowel (open arrow) measures up to approximately 4 cm in diameter. 5 of 5 readers were in agreement for the stricture key imaging finding, with all choosing the option: "Luminal narrowing with moderate-severe upstream dilatation (> 4 cm)." 5 of 5 readers also were in agreement for the stricture impression statement, with all choosing the option: "Stricture with imaging findings of active inflammation".

(54%) exams for segmental mural hyperenhancement to 47 of 50 (94%) exams for presence of penetrating disease. The frequency at which four or more readers agreed for standardized impression statements ranged from 35 of 50 (70%) for the inflammation statement to 48 of 50 (96%) for the stricturing disease statement.

Penetrating disease has particular implications for patient therapy and management. Twenty-eight exams were identified by at least one reader as having penetrating disease. Of these 28 exams, 13 exams with suspected penetrating disease were identified by only one reader. Of the 15 exams identified by more than one reader as having penetrating disease, at least four of five readers agreed about the type of penetrating disease in only five of 15 (33%) exams. Inter-reader agreement for the type of penetrating disease was fair (κ 0.25 [95% CI 0.13–0.38]).

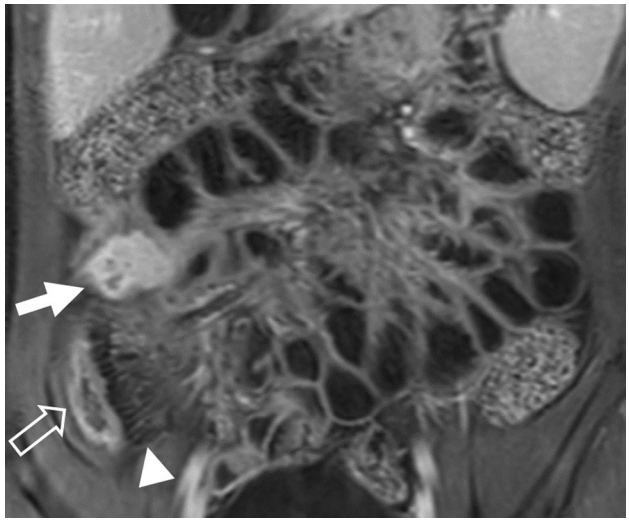

Fig. 2. Coronal T1-weighted fat-saturated post-contrast MR enterography image demonstrates penetrating disease (solid arrow) associated with the terminal ileum (open arrow), which has a heterogenous appearance. Note the engorged vasa recta (arrowhead) at the mesenteric border of the inflamed terminal ileum. 5 of 5 readers were in agreement for the presence of penetrating disease in this patient. However, agreement was lacking for the type of penetrating disease, with 1 reader choosing "complex fistula", 2 readers choosing "inflammatory mass", and 2 readers choosing "abscess.".

Modality-specific inter-reader agreement

When comparing CT vs. MRI, the 95% CI overlapped for each standardized impression and key imaging finding, suggesting no significant difference in agreement between modalities (Table 2).

Discussion

Our study aimed to evaluate inter-reader agreement among a group of pediatric radiologists using the recently published SAR-AGA consensus recommendations for interpreting and reporting CT and MR enterography exams performed in pediatric and young adult patients. Our results show moderate to substantial agreement for the standardized impression statements. Importantly, the greatest levels of agreement were for the conditions that are most likely to require surgical or procedural intervention: stricturing disease (Fig. 1), for which agreement was substantial (κ 0.79), and penetrating disease, for which agreement was moderate (κ 0.58). Agreement regarding the overall inflammation impression statement, which might be used to adjust (e.g., escalate) medical therapy, was somewhat lower but still moderate (κ 0.50).

Interestingly, while agreement on impression statements was moderate to substantial, agreement for key

imaging findings, which radiologists should rely upon to construct their impression statements, was only fair to moderate. As with the impression statements, agreement was relatively higher for presence of a stricture (κ 0.59) and presence of penetrating disease (κ 0.60). Agreement was clustered in the fair to moderate range for the findings most important to identifying small bowel inflammation, including segmental mural hyperenhancement (κ 0.41), bowel wall thickening (κ 0.41), intramural edema on MRI (κ 0.47), and ulcerations (κ 0.37). The lowest level of agreement was for classification of the type of penetrating disease (κ 0.25) (e.g., inflammatory mass vs. complex fistulous disease, inflammatory mass vs. abscess) (Fig. 2). This lack of agreement has potential clinical implications, as differentiating the types of penetrating complications may indicate a need for antibiotic therapy, percutaneous drainage, or surgery.

When comparing CT to MRI, there was no statistically significant difference in agreement (defined as lack of overlap in the 95% confidence intervals) for any of the key imaging findings or impression statements based on modality (CT vs. MRI). However, we do observe some potentially important trends when comparing modalities. The kappa statistic was more than a full category higher for CT vs. MRI (i.e., a difference of > 0.2) for multiple key imaging findings including: type of penetrating disease (CT κ 0.38, MR κ 0.17, κ difference = 0.22) and engorgement of the vasa recta (CT κ 0.69, MR κ 0.47, κ difference = 0.22). These trends are in line with a recent study of 84 patients with active Crohn disease that found better performance of CT enterography than MR enterography for identifying perienteric features of Crohn disease in pediatric and adolescent patients [25]. The kappa statistic also was more than a full category higher for the stricturing disease impression statement in the CT group (CT κ 0.94, MR κ 0.66, κ difference = 0.28), but the 95% CI is very broad (CT κ 0.94, 95% CI 0.25–1.0), limiting our ability to make an absolute conclusion about this difference.

Overall, our results show agreement levels for both key imaging findings and impression statements that are roughly in line with other imaging studies focused on inter-reader agreement for CT and MR enterography. A recent study of MR enterography in pediatric Crohn disease that studied inter-reader agreement between two radiologists for fifteen individual imaging findings found fair to moderate agreement for 11 of the 15 imaging findings that they evaluated (7 findings with κ 0.41–0.60 and 4 findings with κ 0.21–0.40), with 2 findings each in the substantial (κ 0.61–0.80) and poor (κ 0.01–0.20) categories [26]. The authors of a prior study of CT enterography that evaluated inter-reader agreement showed agreement levels that were moderate to substantial, but the study assessed only five imaging findings with two readers [27]. A group that evaluated two-reader agreement for the presence or absence of intestinal inflammation found a κ = 0.86 for CT enterography and a κ = 0.59 for MR enterography, but these results are only indirectly comparable to our study as we did not present our readers with a dichotomous choice for the presence of inflammation [28, 29]. More relevant, a study of MR enterography in the adult Crohn disease population found inter-reader agreement ranging from fair to substantial (κ = 0.3 to 0.69) for 17 individual imaging features of small bowel or mesenteric inflammation [30].

As previously stated, we designed our study to assess baseline variability in the application of the SAR-AGA consensus recommendations to the interpretation and reporting of clinical enterography exams. We did not design our study to assess the impact of education, but we suspect that targeted education may help to reduce variability in this standardized reporting scheme. Specifically, we envision an image- or case-based program, as trialed in prior studies [31, 32]. The creation and publication of an imaging atlas based on the SAR-AGA nomenclature also could be a useful endeavor.

Our study has limitations. It was a retrospective study in which the readers were blinded to one another and to the original reports and to the specific mix of cases with regards to disease activity/phenotype, though all disease cases involved the terminal ileum. Also, the readers in this study, while experienced in interpreting CT and MR enterography exams, had no significant previous experience with the SAR-AGA consensus document and its reporting recommendations prior to this study, as it was only recently drafted and published. This certainly limited their familiarity with the recommended nomenclature in the document.

In conclusion, our study finds moderate to substantial inter-reader agreement for the use of standardized impression statements and fair to moderate agreement for assessment of key imaging findings when utilizing new SAR-AGA consensus recommendations for the interpretation and reporting of CT and MR enterography in pediatric and young adult small bowel Crohn disease patients. When comparing modalities, we found slightly higher agreement levels for some key imaging findings with CT enterography compared to MR enterography, but no substantial difference in agreement for overall impression statements. When adopting the SAR-AGA recommendations, we posit that targeted radiologist education, perhaps image- or case-based as trialed in prior studies, may be needed to minimize variability in the standardized reporting of enterography exams and maximize the value of the standardized reporting scheme.

Compliance with ethical standards

Funding This study was not funded.

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

Informed consent The requirement for informed consent was waived by the institutional review board.

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