Pediatr Radiol (2017) 47:917–923
DOI 10.1007/s00247-017-3849-2

ORIGINAL ARTICLE

# Can ultrasound be used as the primary imaging in children with suspected Crohn disease?

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Received: 7 October 2016 / Revised: 24 January 2017 / Accepted: 23 March 2017 / Published online: 22 April 2017


**Abstract**
*Background* There is growing literature on the use of ultrasound (US) for evaluation of Crohn disease in adults, but few studies have been conducted on children. Several studies demonstrated high accuracy of US in the diagnosis of Crohn disease. Using US as the primary screening imaging modality for Crohn disease can reduce health care costs, the need for sedation and ionizing radiation exposure.
*Objective* The aim of our study is to determine if US can be used for screening evaluation of pediatric Crohn disease.
*Materials and methods* A prospective cohort study of pediatric patients undergoing MR enterography (MRE) for suspected or known history of Crohn disease was performed, with gray-scale and Doppler US of the terminal ileum done immediately before or after MRE. US images were interpreted by two radiologists (Reader 1 and Reader 2) not involved in image acquisition, in blinded and randomized fashion. US findings of Crohn disease including bowel wall thickening, wall stratification, increased vascularity on Doppler, lymphadenopathy, fat infiltration and extraintestinal complications were evaluated. MRE findings of terminal ileitis were considered the reference standard. Demographic data, body mass index (BMI), symptoms, and laboratory, endoscopic and histopathological data were obtained from electronic medical records.
*Results* Forty-one patients (mean age: 13.7 years: 4.6-18.9 years) were evaluated. Mean BMI was 21.2 (range: 13-40.2); 10 patients (24.3%) were either overweight or obese. Final diagnoses were Crohn disease ($n$=24), ulcerative colitis ($n$=4) and normal/non-inflammatory bowel disease-related diagnoses ($n$=13). US demonstrated sensitivity of 67% and 78% and specificity of 78% and 83%, by Reader 1 and Reader 2, respectively. MRE sensitivity and specificity were 75% and 100%, respectively, compared to final clinicopathological diagnosis. Interobserver agreement between Reader 1 and Reader 2 was good (0.6< kappa <0.8).
*Conclusion* In screening for Crohn disease in children, US has limited sensitivity for detecting terminal ileitis.

**Keywords** Children · Crohn disease · Inflammatory bowel disease · Magnetic resonance enterography · Ultrasound

## Introduction

Crohn disease is an inflammatory bowel disease (IBD) that may affect any portion of the gastrointestinal tract, most commonly involving the terminal ileum. It is characterized by recurrent episodes of inflammation and may result in complications including intestinal strictures and fistulas. Although Crohn disease is more common in adults, 25% to 30% of diagnoses occur before the age of 20 and thus may have deleterious effects on growth and development [1, 2].

Optimal management of Crohn disease relies on a combination of clinical information, serologic markers, imaging, endoscopic procedures and histological examination. Recent advances in imaging have made computed tomography enterography (CT enterography) and magnetic resonance

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enterography (MRE) the imaging studies of choice in the evaluation of Crohn disease over small bowel follow-through, due to their increased sensitivity and ability to depict extraluminal complications and disease activity. Particularly in children, MRE may be preferable to CT enterography as it does not involve ionizing radiation. However, MRE is costlier and may require sedation in young or uncooperative patients. Furthermore, due to the chronic relapsing nature of Crohn disease, these children may require multiple imaging studies to assess treatment response, reactivation of disease and complications. Therefore, neither of the primary cross-sectional imaging modalities are ideal in children.

Ultrasonography (US) is an established noninvasive imaging modality that can demonstrate the presence or absence of Crohn disease in the bowel, as well as assess for disease activity and complications. US does not use ionizing radiation and is also inexpensive compared to CT enterography and MRE. Bowel US has been a routine part of IBD evaluation in Europe for more than 20 years [3, 4]; however, this modality is only now becoming established in the evaluation of patients in North America [4–10]. While the efficacy of US to evaluate Crohn disease in adults has been validated by many studies in Europe, to our knowledge there are few studies in children in either Europe or North America [5–8]. Despite this limitation, several authors already suggest using US as the first line of imaging for screening and follow-up of Crohn disease in children [3–10].

The primary aim of our study is to determine the utility of US as a screening tool in children with suspected Crohn disease. We used MRE as the reference standard and prospectively evaluated the diagnostic yield of US for identifying inflammatory changes in the terminal ileum.

## Materials and methods

### Patients

This prospective, HIPAA-compliant study was approved by our institutional review board. Informed consent was obtained. Patients in our study included children (≤18 years old) who underwent MRE (June 2014 to February 2016) for evaluation of IBD in a tertiary-care referral center and agreed to undergo a limited abdominal US. This study selected only patients in whom MRE was performed during daytime working hours (08:00–17:00 h). Patients underwent US examination either immediately before or after MRE, depending on scanner availability.

From the electronic medical records, we retrieved the demographic data, body weight, height, symptoms, laboratory results (white blood cell count [WBC], erythrocyte sedimentation rate [ESR], C-reactive protein [CRP]), and endoscopic and pathology results. Patient body mass index (BMI) and weight status category was determined with patient gender and age per Centers for Disease Control and Prevention (CDC) growth charts and guidelines [11].

### Imaging protocol

MR studies were performed using 1.5-T (Avanto; Siemens, Malvern, PA) or 3-T (Trio; Siemens, Malvern, PA) systems. MRE was performed following oral administration of 800 mL of oral contrast (Volumen; Bracco Diagnostics, Princeton, NJ). All studies included coronal and axial True FISP (fast imaging with steady-state precession) and HASTE (half-Fourier acquisition single-shot turbo spin-echo) sequences, axial diffusion, and pre- and post-IV contrast (Multihance; Bracco Diagnostics Inc., Singen, Germany). Axial VIBE (volumetric interpolated breath-hold examinations) were obtained after 15 s, 60 s and 2 min followed by coronal VIBE. During the study, intravenous glucagon was administered as follows: 0.25 mg×2 for patients with body weight less than 50 kg and 0.5 mg×2 for all other patients.

Transabdominal longitudinal and transverse US of the patient's right lower quadrant were performed and any image demonstrating pathology as well as transverse or transverse oblique images along the main axis of the terminal ileum were saved. The studies were performed by either an US technologist with 9 years of experience or one of the two fellowship-trained pediatric radiologists (M.B.M. and B.K. with 4 years and 18 years of experience, respectively). The studies were performed with an iU22 system (Philips Healthcare, Aurora, IL). According to the body habitus, we used either a high-resolution 5–17 MHz or 5–12 MHz linear transducer for assessment of terminal ileum, adjacent mesenteric fat and lymph nodes. Color Doppler was performed with low flow settings and with a velocity scale range of 4.5 cm/s.

### Image analysis

Examinations were reviewed on PACS (Synapse; Fujifilm Medical Systems, Stamford, CT).

MRE studies were reviewed by a fellowship-trained pediatric radiologist (M.L.C. with 2 years of experience) for the presence of IBD and involvement of the terminal ileum. The wall of the terminal ileum was measured in three locations. The wall of the terminal ileum was evaluated for presence of wall stratification, increased enhancement, restricted diffusion and extraintestinal complications. The subcutaneous fat at the right paraumbilical area was measured anterior to the rectus abdominal muscle in the axial T2 HASTE series.

US examinations were reviewed independently and blinded to MRE results in a randomized order by two additional fellowship-trained pediatric radiologists (Reader 1 and Reader 2) for findings of ileitis. The wall

of the terminal ileum was measured in three different locations, and the presence of lymphadenopathy, increased echogenicity, the quantity of adjacent fat and extraintestinal complications were noted. The vascularity of the terminal ileum was assessed as normal (≤2 vessels per $cm^2$), mild (3–5 vessels per $cm^2$), moderate (6–8 vessels per $cm^2$) or marked (>8 vessels per $cm^2$). The study was considered positive if there was any change in wall stratification, increased vascularity as defined above and any subjective increase in bowel wall thickness.

The quality of the study was subjectively graded as poor, average or excellent based on how well the terminal ileum wall was shown.

### Statistical analysis

US sensitivity and specificity were evaluated using MRE diagnosis of terminal ileitis as the reference standard. MRE sensitivity and specificity were evaluated using final endoscopic and histopathological diagnosis. We considered equivocal US results as positive because in clinical practice they generally lead to further evaluation by other imaging modalities (CT enterography or MRE).

Mean bowel wall thickness, vascularity and the presence of bowel wall stratification were compared between children with and without Crohn disease by the Student's *t*-test, chi-square test and Fisher exact test, respectively.

Mean bowel wall thickness on US was compared to mean wall thickness on MR and wall enhancement with Spearman correlation coefficients and the Fisher exact test, respectively. From measurements of average wall thickness by Reader 1 and Reader 2, wall thickness cutoffs were determined that provided a sensitivity of at least 90% for diagnosing Crohn disease.

Inter-reader variability of mean wall thickness and wall vascularity was evaluated using interclass correlation coefficient (ICC) and Bland-Altman analysis with limits of agreement. ICC>0.75 indicates a good level of agreement, 0.50 to 0.75 indicates a moderate level of agreement and <0.50 indicates a poor level of agreement.

Kappa coefficients were calculated to evaluate agreement between Reader 1 and Reader 2 in assessment of study quality. Kappa was defined as fair, 0.21–0.40; moderate, 0.41–0.60; good, 0.61–0.80, and very good, 0.81–1.00. We also compared quality grading of the study versus obesity as defined by patient gender and age per CDC as BMI of 95th percentile or greater [11]. We used the Mantel-Haenszel test to evaluate the difference in quality between underweight or normal patients and overweight or obese patients. The Fisher exact test was used to evaluate differences in the quality of US studies performed before or after MRE. One-way analysis of variance (ANOVA) was used to assess correlation between the quality of the US study and abdominal wall thickness. Analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC) and significance was defined as $P<0.05$.

## Results

### Patient demographics and clinical presentation

Patient characteristics, symptoms, indication for MRE and final diagnoses are depicted on Table 1. The most

**Table 1** Study patient characteristics ($n$=41)

| | |
|---|---|
| Age (years) | Mean: 13.7 (range: 4.6 to 18.9) |
| Female | 19 (46.3%) |
| Mean BMI | 21.2 (range: 13 to 40.2) kg/$m^2$ |
| Patient weight status | |
| Obese (BMI ≥95th percentile) | 5 (12.2%) |
| Overweight (BMI 85th to 95th percentile) | 5 (12.2%) |
| Normal (BMI 5th to 85th percentile) | 23 (56.1%) |
| Underweight (BMI <5th percentile) | 8 (19.5%) |
| Symptoms | |
| Abdominal pain | 18 |
| Diarrhea | 13 |
| Bloody diarrhea | 8 |
| Weight loss | 7 |
| Reason for MRE exam | |
| Abdominal pain | 18 |
| Follow-up of known Crohn disease | 14 |
| Diarrhea/constipation | 5 |
| Lack of expected growth with elevated ESR | 1 |
| Erythema nodosum | 1 |
| Perianal fistula | 1 |
| Appendicitis complicated by abscesses | 1 |
| Final diagnosis | |
| Crohn disease | 24 (58.5%) |
| Ulcerative colitis | 4 (9.8%) |
| Normal/non-IBD-related diagnoses | 13 (31.7%) |

*BMI* body mass index, *ESR* erythrocyte sedimentation rate, *IBD* inflammatory bowel disease, *MRE* magnetic resonance enterography

common indications for MRE were abdominal pain (43.9%, 18/41) and diarrhea (31.7%, 13/41). The indication for MRE in 14 patients was follow-up of known Crohn disease, with seven patients symptomatic.

### Laboratory, endoscopy and pathology findings

Of the 41 patients enrolled in our study, 36 had a complete blood count within 90 days of their MRE/US. Twenty-three (56%) patients had elevated WBC and/or inflammatory indices (CRP and ESR).

Endoscopy was performed in all 41 patients. Biopsy records were obtained from 40 patients; one patient with endoscopic diagnosis of ulcerative colitis did not have a record of biopsy. The mean time interval of biopsy from the time of the patient's US study was 178 days (median: 45 days, range: 11 to 1,126 days). The final diagnosis based on pathology was Crohn disease in 24 patients; 20 of them had endoscopic findings typical for Crohn disease and 4 patients had nonspecific inflammatory changes on endoscopy. Endoscopy demonstrated strictures in two patients with Crohn disease.

Diagnosis of ulcerative colitis was based on pathology in three patients and only on endoscopy in one patient. The other 13 patients did not have IBD.

In 29 of the 41 patients, the terminal ileum was assessed on colonoscopy. Nine patients did not have their terminal ileum assessed due to technical difficulty ($n$=4), severe inflammation ($n$=4) or stool ($n$=1). Three patients had incomplete records that did not indicate details regarding the terminal ileum on endoscopy.

### MRE

MRE demonstrated inflamed bowel in 18 (75%) of the 24 patients with histopathology diagnosis of IBD, all of whom demonstrated inflammation of the terminal ileum. MRE was negative in all 17 patients without Crohn disease, yielding a sensitivity of 75% (95% confidence interval [CI]: 58–92%) and specificity of 100% (95% CI: 100–100%) for Crohn disease. One patient had an enteroenteric fistula and another had a phlegmon as a complication of Crohn disease.

### US

US studies were rated as poor quality in 4/41 (10%) patients by Reader 1 and 6/41 (15%) patients by Reader 2. Poor quality was attributed to obesity in each of these cases by the two radiologists (Fig. 1). There was significant decrease in the quality of the US studies in overweight ($n$=5, 2 with Crohn disease) and obese ($n$=5, 1 with Crohn disease) patients as compared with the normal ($n$=23, 16 with Crohn disease) and underweight ($n$=8, 5 with Crohn disease) patients ($P$=0.0019 and $P$=0.0057 for reviewers 1 and 2, respectively).

There was also significant association ($P$=0.0002 for Reader 1 and $P$<0.0001 for Reader 2) between US study quality and subcutaneous fat thickness. The average thickness of subcutaneous fat was 9 mm and 12 mm (Reader 1 and Reader 2) for US studies rated as excellent in quality, 21 mm and 22 mm (Reader 1 and Reader 2) for average quality and 36 mm and 40 mm (Reader 1 and Reader 2) for poor quality. There was no significant difference in quality between the US

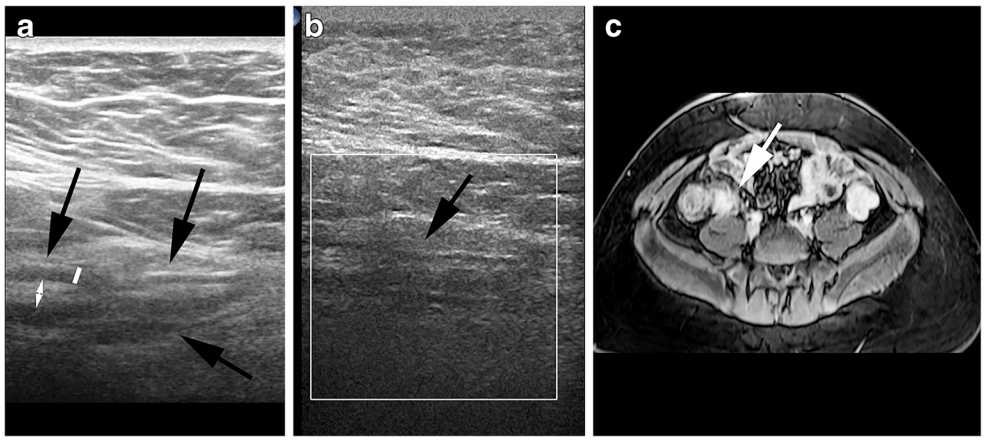


**Fig. 1** A false diagnosis of normal terminal ileum by ultrasound in an obese 16-year-old girl with Crohn disease. Long-view gray-scale US (**a**) shows the challenge of penetrating the thick subcutaneous fat with suboptimal demonstration of the terminal ileum (*arrows*), wall thickness (*white line*) and lumen (*double-headed arrow*). Color Doppler was negative (*arrow*, bowel wall) (**b**). Postcontrast arterial phase enhancement volumetric interpolated breath-hold examination with fat suppression (VIBE FS) MRI demonstrates terminal ileitis (*arrow*, **c**)

studies performed before and after the MRE ($P$=0.71 and 0.31 for reviewers 1 and 2, respectively).

In the 41 patients, terminal ileitis was diagnosed in 7 (17.1%) and 14 (34.1%) patients (Fig. 2), equivocal in 9 (22.0%) and 5 (12.2%) patients, and absent in 25 (61.0%) and 22 (53.7%) patients by Reader 1 and Reader 2, respectively.

Considering both positive and equivocal US findings as positive for Crohn disease, the sensitivity of US was 67% and 78% and the specificity was 83% and 78% for Reader 1 and Reader 2, respectively.

Mean bowel wall thickness measured by US was compared in patients with ($n$=18) and without ($n$=23) findings of Crohn disease on MRE. The bowel wall was significantly ($P$<0.001) thicker (2.5±1.1 mm and 3.5±1.6 mm, Reader 1 and Reader 2, respectively) in patients with Crohn disease compared with other patients (1.5±0.8 mm and 1.8±0.8 mm, Reader 1 and Reader 2, respectively). From average bowel wall thickness measurements by Reader 1, a bowel wall thickness greater than 1.9 mm provided a sensitivity of 91% and specificity of 61% in differentiating bowel affected or not affected by Crohn disease. For Reader 2, a bowel wall thickness greater than 1.8 mm provided a sensitivity and specificity of 91% and 83%, respectively.

Five patients did not have vascularity documented on US. Increased terminal ileum vascularity was significantly ($P$=0.03) more common in patients with MRE evidence of terminal ileitis only for Reader 1 (9/15, 60% vs. 5/21, 23.8%) but not significant ($P$=0.07) for Reader 2 (11/15, 73.3% vs. 9/21, 42.9%).

Loss of wall stratification was significantly ($P$=0.004) more common in patients with MRE evidence of terminal ileitis only for Reader 1 (6/18, 33.3% vs. 0) but not significant ($P$=0.29) for Reader 2 (6/18, 33.3% vs. 4/23, 17.4%).

None of the US studies demonstrated extra-intestinal complications.

Interobserver agreement between Reader 1 and Reader 2 for the diagnosis of Crohn disease was found to be good (0.6< kappa <0.8). The mean difference of wall thickness average between Reader 1 and Reader 2 was 0.56 mm (95% CI: -4.00–0.83 mm). Inter-reader variability for measurement of bowel wall thickness was moderate (ICC=0.64). Inter-reader variability in detecting increased bowel wall vascularity was good (ICC=0.84).

## Discussion

US has emerged as an alternative imaging modality for the diagnosis and follow-up of Crohn disease in children [3–10], with a few studies, mainly on adults, showing sensitivity and specificity comparable to CT enterography and MRE [12, 13]. In children, the sensitivity of US ranges from 48% to 88% with a specificity range of 57% to 100% [14–19]. The use of US for evaluation of Crohn disease started in Europe and is now being introduced in the United States [4–10, 20]. As a tertiary pediatric medical center with extensive pediatric US experience and a high-volume Crohn disease clinic, our study aim was to evaluate the utility of US as a first-line imaging modality for evaluating Crohn disease in children with clinical suspicion of IBD. Currently in our practice, MRE serves as the preferred imaging modality for evaluating both suspected IBD and follow-up of patients with known IBD.

We evaluated only the terminal ileum in our study, as it is the most commonly involved bowel segment in Crohn disease, [2] and is in a well-defined anatomical location. All patients in our study with MRE positive studies for Crohn disease demonstrated terminal ileitis. There have been three other studies by Faure et al. [15], Epifanio et al. [16], and Haber et al. [17]

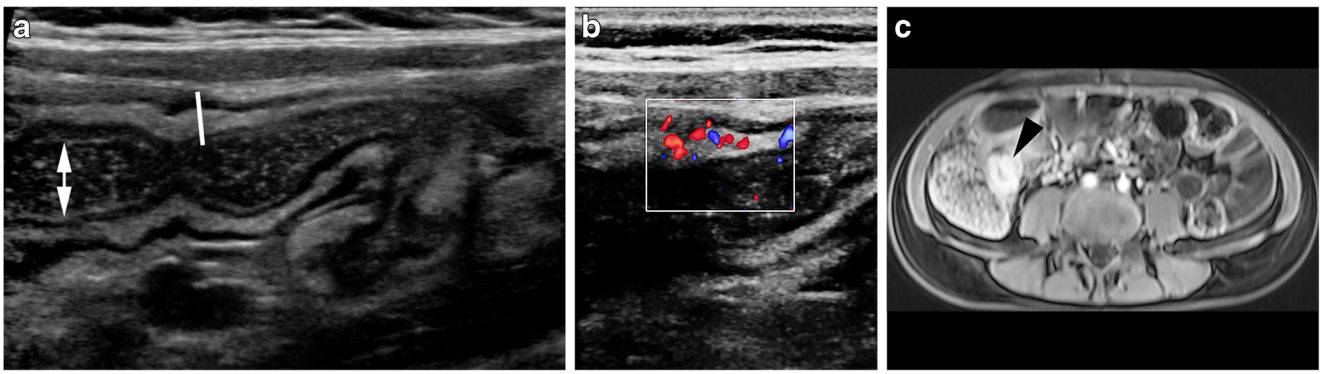


**Fig. 2** A diagnosis of terminal ileitis by ultrasound in a 16-year-old girl with Crohn disease. Long-view gray-scale US shows the thickened terminal ileum (**a**), wall thickness (*white line*) and lumen (*double-headed arrow*) with marked increased vascularity on color Doppler (**b**). Postcontrast arterial phase enhancement volumetric interpolated breath-hold examination with fat suppression (VIBE FS) MRI demonstrates terminal ileitis (*arrowhead*, **c**)

that correlated US terminal ileitis to colonoscopy. Wall thicknesses >2.5 mm [15], >3 mm [16] or >1.5 mm [17] were the only US criteria used in these studies as the positive finding for terminal ileitis. Sensitivity in all three studies was 100% [15–17]. Specificity, however, ranged from 72% to 92% [15–17]. Considering both positive and equivocal US findings as positive for Crohn disease, the sensitivity of US in our study was 67% and 78% and the specificity was 78% and 83%, for Reader 1 and Reader 2, respectively.

We found that bowel wall thickness was the only finding that was significantly different ($P<0.001$) in patients with Crohn disease according to the two radiologists' observations. Bowel wall thickness was 2.5±1.1 mm and 3.5±1.6 mm (Reader 1 and Reader 2, respectively) in patients with Crohn disease compared with 1.5±0.8 mm and 1.8±0.8 mm (Reader 1 and Reader 2, respectively) in other patients. In a retrospective analysis of bowel wall thickness, we found that bowel wall thickness of 1.9 mm and 1.8 mm had sensitivity ≥91% for Crohn disease with a specificity of 61% and 83% for Reader 1 and Reader 2, respectively. A recent study correlating US and MRE in children with Crohn disease used bowel wall thickening of ≥4 mm as a criterion for bowel wall thickening [7]. This study evaluated all segments of the small bowel loops and colon. For the terminal and distal ileum, the sensitivity was 0.52 (0.30–0.74) with a specificity of 0.91 (0.59–0.99), confirming our results that a smaller bowel thickness should be used to increase the sensitivity of US.

Our study findings suggest that US is technically limited in obese children. US studies were rated as poor quality in 9.8% and 14.6% (4 and 6 of the 41) patients by Reader 1 and Reader 2, respectively. It was surprising to us that 7 of 27 patients (25.9%) with suspected Crohn disease and 3 of 24 patients (12.5%) with established Crohn disease were overweight/obese. This is thought to be the major factor limiting US study quality as the thickness of subcutaneous fat was found to correlate significantly with the quality of the study. In children with US studies rated as excellent in quality, the subcutaneous fat thickness was 9 mm and 12 mm (Reader 1 and Reader 2, respectively), while in poor quality US studies, the subcutaneous fat thickness was three to four times thicker (36 mm and 40 mm, Reader 1 and Reader 2, respectively). Several other studies have also noted the limited utility of US for Crohn disease in obese patients [3] and obscuration by overlying bowel gas [17]. Other potential limitations include limited field of view, limited penetration in deeply located bowel loops, and dependence on sonographer/radiologist skill and experience. In addition, interobserver variability may also limit the use of US [20].

Our study has a few advantages over prior studies. Many studies used endoscopy and/or biopsy as the reference standard [14–19, 21]. In a study by Ziech et al. [14], US was performed on the same day as MRE and colonography; however, sensitivity and specificity of US were compared to colonoscopy, which was performed on average 7.5 days (1–40 days) from the US study. Likewise, in many other studies, US was not performed at the time of endoscopy and therefore the pathology could have changed by the time US was performed [15–19]. For this reason, we chose MRE performed immediately before or after US as the reference standard. Compared to pathology, MRE had a specificity of 100% and was falsely negative in only two patients who were treated for Crohn disease, likely representing disease remission. Other studies had less-defined reference standards such as colonoscopy, barium follow-through, or a combination of radiology, endoscopy and pathology [6, 21].

A recent study by Ahmad et al. [7] also used MRE performed as the gold standard. This study on 33 patients evaluated all segments of small bowel loops and colon. The study found good correlation (Kendall Coefficient of Concordance-0.75) between consensus read of US and MRE of the distal and terminal ileum. This study does not provide results on the overall sensitivity and specificity of US. However, the low US sensitivity of wall thickness and increased wall vascularity (mean: 52% and 26%, respectively) is in agreement with our study that the sensitivity of US in diagnosis inflammation in the terminal ileum in children with Crohn disease is limited.

In most prior studies, the US scans were reviewed by only one investigator who was not blinded to the clinical diagnosis [14–19]. In only one study, the US technician performing the study was blinded to all clinical information [15]. In our study, the US technician and radiologists who performed the US studies as well as the radiologists reading the US studies were blinded to clinical information and MRE results. The two radiologists interpreted the US studies independently, blinded to clinical information and in randomized order. Only one study by Dillman et al. [20] evaluated interobserver variability in children with Crohn disease. This study was performed as a follow-up of complications and disease activity in children with Crohn disease. The interobserver variability for disease activity (wall thickness and bowel wall Doppler) was moderate to good, which is comparable to our results of good interobserver agreement (0.6< kappa <0.8) for the presence of Crohn disease. Interobserver variability was moderate (ICC=0.64) for wall thickness and good (ICC=0.84) for increased wall vascularity.

Our study has several limitations. About a third of the children with Crohn disease do not have inflammation of the terminal ileum [22]. Other studies demonstrated that the US sensitivity and specificity for Crohn disease were highest in the terminal ileum [7, 15, 17, 18]. Our study may therefore overestimate the performance of US in the diagnosis of Crohn disease. The number of patients was relatively small ($n=41$). However, our sample size was similar to other studies with study populations ranging from 28 to 75 patients [7, 14–19]. In addition, the radiologists interpreting the US studies were not involved in US image acquisition, resulting in loss of real-time information that may not have been recorded for image interpretation. However, the advantage to such a restrictive approach is the limitation of bias for the radiologist, as communication

with patients may influence interpretation of the study. In addition, the diagnosis of terminal ileitis by the radiologists was not determined by well-defined wall thickness criteria, but rather a combination of wall thickness, loss of wall stratification and increased vascularity. Other limitations were the lack of oral contrast in all patients and not using intravenous contrast-enhanced US. Pallotta et al. [19] demonstrated improved sensitivity (96–100% vs. 75–76%) while maintaining 100% specificity of small intestinal contrast US compared to conventional transabdominal US. Few studies have been conducted on the use of contrast-enhanced US for Crohn disease, of which both adult and pediatric populations were included [23, 24]. A meta-analysis demonstrated pooled sensitivity of 94% (95% CI: 87–97%) and pooled specificity of 79% (95% CI: 67–88%) [24]. This technique allows for improved detection and analysis of bowel perfusion and may prove to increase US accuracy. However, at this time, the use of IV contrast US has not been approved by the U.S. Food and Drug Administration for this application.

## Conclusion

Our study demonstrated low US sensitivity for the detection of terminal ileitis in patients with Crohn disease and did not detect either case with extraintestinal complication. Using a wall thickness >2 mm as a criterion for Crohn disease may have increased the sensitivity. Patient body habitus was the main factor limiting US study quality. In addition, there was significant variability in wall thickness and vascularity measurement compared to MRE. These findings suggest that US cannot be used as the initial imaging modality for evaluating children with suspected Crohn disease. More prospective studies with the use of contrast-enhanced US and full evaluation of the bowels are suggested to find if US has any role in the initial diagnosis or follow-up of children with Crohn disease.

**Compliance with ethical standards**

**Conflicts of interest** None

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