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Diagnostic performance of magnetic resonance enterography and ultrasound in children with inflammatory bowel diseases: a diagnostic test accuracy meta-analysis

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Abstract

Objectives Magnetic resonance enterography (MRE) and ultrasound (US) can be used to diagnose inflammatory bowel diseases (IBD) in children. This meta-analysis aimed to determine the diagnostic performance of MRE and US in pediatric patients with IBD.

Methods PubMed, Embase, and the Cochrane Library were searched for eligible studies published up to June 1, 2020. The outcomes were the performances of MRE and US at the segment and patient levels. Pooled sensitivity, specificity, positive and negative likelihood ratios (PLR and NLR), diagnostic odds ratio (DOR), and the area under the summary receiver operating characteristic curves value (SROC) were analyzed.

Results Eight studies (340 children) were included. Compared with the reference standard, MRE showed pooled sensitivity of 93.0% (95% confidence interval (CI): 90.0–95.4%), specificity of 94.6% (95% CI: 92.1–96.5%), PLR of 11.146 (95% CI: 5.027–24.713), NLR of 0.094 (95% CI: 0.057–0.155), and DOR of 134.21 (95% CI: 40.72–442.29), with a SROC of 0.9721. Similar results were observed at the patient and segment levels. Compared with the reference standard, US had pooled sensitivity of 84.1% (95% CI: 69.9–93.4%), specificity of 82.9% (95% CI: 66.4–93.4%), PLR of 4.924 (95% CI: 2.351–10.310), NLR of 0.207 (95% CI: 0.103–0.413), and DOR of 25.919 (95% CI: 7.63–88.07), but only two studies were included. US (reader 1) had a similar diagnostic value to US (reader 2).

Conclusions The present meta-analysis shows that MRE has good performance in detecting IBD in pediatric patients. Only two studies used US, and additional studies are necessary to confirm the diagnostic performance of US for IBD in children.

Key Points

- *MRE has good performance in the detection of IBD in pediatric patients.*
- *Similar results were observed at the patient and segment levels for MRE.*
- *Only two studies were included for US, without differentiating patient/segment.*

Keywords Magnetic resonance imaging · Ultrasonography · Children · Crohn disease · Ulcerative colitis

Abbreviations

CD	Crohn disease
CI	Confidence interval
CT	Computed tomography
DOR	Diagnostic odds ratio
DWI	Diffusion-weighted imaging
IBD	Inflammatory bowel diseases
MRE	Magnetic resonance enterography
MRI	Magnetic resonance imaging
PLR and NLR	Pooled sensitivity, specificity, positive and negative likelihood ratios
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses

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QUADAS-2	Quality Assessment of Diagnostic Accuracy Studies
SROC	Summary receiver operating characteristic curves value
UC	Ulcerative colitis
US	Ultrasound

Introduction

Crohn's disease (CD) is a chronic inflammatory, multisystem disorder, mainly affecting the gastrointestinal tract, more typically the small bowel (especially ileum) or colon [1–3]. Ulcerative colitis (UC) is a chronic colonic inflammatory disease with proximal extension from the rectum but without small bowel involvement [1–4]. About 20–30% of patients with CD are diagnosed during childhood [1, 3], but children can suffer from CD, with an incidence of 0.3–9.2 per 100,000 children worldwide [3]. The reported incidence of UC is 0.2–6.7 per 100,000 children in North America and Europe [3, 5]. Children with CD or UC are at risk of intestinal and abdominal complications, macronutrient and micronutrient deficiency, poor bone health, anemia, and impaired growth [1–3, 6, 7]. The management of pediatric CD involves drugs and sometimes surgeries [1–3, 7].

The diagnosis of inflammatory bowel disease (IBD) in children is based on symptoms, bloodwork, stool tests, endoscopy, and imaging [1–3, 7]. Ultrasound (US) is a screening tool in the preliminary diagnostic workup of suspected IBD in children, but more sensitive imaging modalities are required for the small bowel [2]. US allows the visualization of bowel thickness, strictures, fistulae, abscesses, and inflammation of the mesentery [3]. The benefits of US include excellent images of the bowel wall, no exposure to ionizing radiations, widely available, well-tolerated, and low cost [3]. US limitations include operator dependency, high interobserver variability, and difficulty distinguishing or visualizing the entire gastrointestinal tract, including the proximal ileum, jejunum, transverse colon, and rectum [2, 3, 7]. Magnetic resonance enterography (MRE) is an imaging technique using magnetic resonance imaging (MRI) with oral intraluminal contrast and intravenous gadolinium [8]. It is the imaging modality of choice in diagnosing pediatric inflammatory bowel disease [1–3]. MRE is preferred over computed tomography (CT) and fluoroscopy due to the lack of ionizing radiation exposure and high diagnostic accuracy [2, 9]. MRE can detect small intestinal involvements, inflammatory changes in the intestinal wall, and fibrosis/inflammation (but it is difficult for MRE to differentiate fibrosis and inflammation clearly) and help identify disease complications (fistula, abscess, stenosis) at diagnosis [2, 3]. MRE can determine the degree of intestinal inflammation and damage, but there is no validated scoring system in children [2]. The limitations of MRE include motion artifacts, difficulties in tolerating oral contrast, high cost, and limited availability compared to other imaging modalities [3].

Because children are more sensitive than adults to ionizing radiation, MRE and US are the methods of choice for the diagnosis and subsequent management of pediatric IBD [2]. A previous meta-analysis showed that MRE has high diagnostic performance in children, especially at the per-patient level [10]. Another meta-analysis showed that capsule endoscopy, MRE, and US all had similar diagnostic yields for small bowel CD [11]. On the other hand, a systematic review suggested that the diagnostic accuracy of US for pediatric IBD was inconclusive [12].

Even though these analyses are recent (2017–2019) [10–12], new evidence has been published that could provide new light on the diagnostic accuracy of MRE and US for IBD in children. In addition, Kopylov et al. [11] included only studies on CD, but it is known that CD and UC can be difficult to differentiate in children [1–4], which could lead to bias. Therefore, this meta-analysis aimed to determine the diagnostic performance of MRE and US in pediatric patients with IBD.

Materials and methods

Literature search

This meta-analysis was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guidelines [13]. Since no original clinical raw data was collected or used, ethical approval was not requested for this meta-analysis.

The eligibility criteria were as follows: (1) pediatric (definition according to each included study but could vary among studies) patients with suspected or known IBD (only IBD, irrespective of fistula or stage); (2) use of MRE or US for diagnosis; (3) the reported data could be used to construct at least one 2 × 2 table for test performance; (4) prospective studies; (5) full text published in English.

PubMed, Embase, and the Cochrane Library were searched for studies published up to June 1, 2020, using the Medical Subject Headings (MeSH) terms "Inflammatory Bowel Diseases", "Crohn Disease", "Colitis, Ulcerative", "Child", "Ultrasonography", and "Magnetic resonance enterography", as well as relevant keywords.

Data extraction and quality assessment

The potentially relevant publications were screened and evaluated by two reviewers (Lili He and Qiong Yao) double-blindly, with a third reviewer (Yinghua Sun) being invited to resolve any disagreement. A structured data collection form was developed. Two researchers (Lili He and Qiong Yao) independently extracted the data, including authors, year of publication, country, sample size, age, percentage of males,

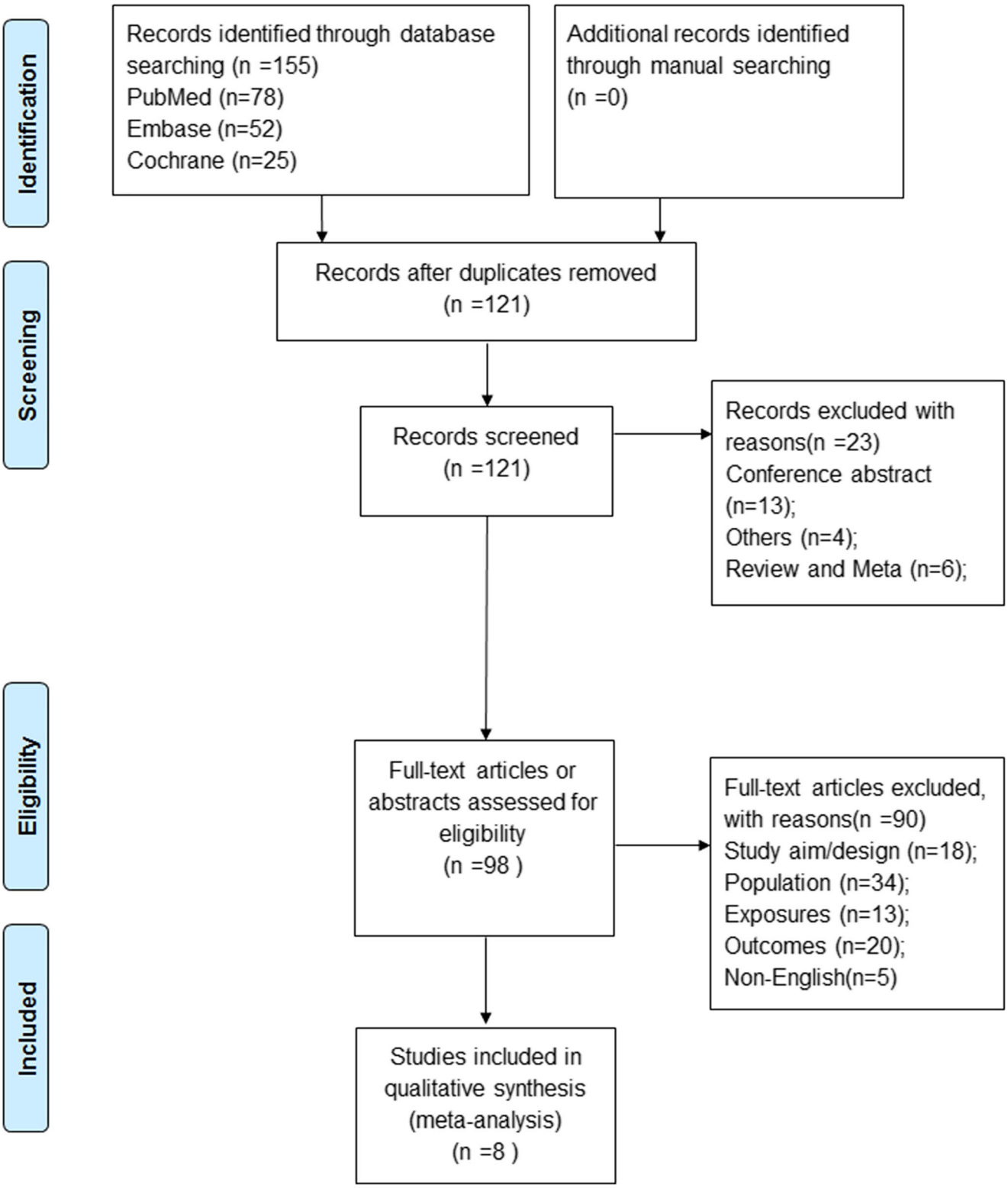

Fig. 1 Flowchart of the search process of our study.

included patients, study aim, the standard of reference, magnet strength or probe frequency, diagnostic criteria, and data for diagnostic performance. The studies were evaluated according to the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool [12].

Table 1 General characteristics of included studies

Study	Sample size	Age (years, mean or range)	Male (%)	Country	Inclusion	Study aim	Standard of reference	Modality compared with standard of reference	Time gap	Magnet strength or probe frequency	MRE/US diagnostic criteria	Analysis level
Casciani 2010 [15]	60	14 (range: 6–18)	36 (60%)	Italy	Suspected CD	Compare the diagnostic yield of MRE with SBCE in pediatric patients with suspected CD	A combination of clinical evaluation, endoscopic, histological, and/or biochemical investigations	MRE		1.5 T	Patients with at least one of the following MRE findings were considered having CD [14]: SB wall thickness (more than 3 mm), SB wall enhancement after intravenous contrast media, SB edema (increased signal intensity of the SB wall compared with normal wall evaluated on T2 sequences), stratified appearance on contrast-enhanced T1-weighted fat-suppressed (mucosal and serosal enhancement, combined with intervening submucosal edema)	Patients
Gee 2011 [16]	21	17.7 (range: 12–22)	10 (47.6%)	USA	Histologically proven CD	Detecting active bowel inflammation and fibrosis using a histologic reference standard	CT; histology	MRE		1.5 T	Prominent mucosal enhancement followed by progressive transmural enhancement on dynamic gadolinium-based contrast agent-enhanced images, prominent mesenteric vasarecta, and bowel wall T2 hyperintensity relative to muscle.	Segments
Quencer 2013 [17]	12	17.2 (range: 12–20)	7 (58.3%)	USA	Known CD	Assess for active inflammation and mural fibrosis in patients with known CD	Histology	MRE	Subsequently underwent surgical bowel resection or endoscopic biopsy within 7 weeks of the imaging studies.	1.5 or 3 T	Active inflammation: avid enhancement especially with an early mucosal, component adjacent mesenteric inflammation, T2 hyperintense bowel wall (c/w adjacent muscle); fibrosis: non-avidly enhancing, T2 iso- to hypointense to adjacent muscle, lack of adjacent mesenteric inflammation.	Segments
Maccioni 2014 [18]	50	13.5 (range: 6–18)	26 (52%)	Italy	Confirmed diagnosis of CD	detecting CD lesions from the jejunum to the anorectal region in pediatric patients	Association of different reference investigations, including HRUS, capsule endoscopy, and barium studies, for the small bowel and ileocolonoscopy for the large bowel.	MRE	Within a maximal interval of 15 days	1.5 T	Concentric wall thickening (> 4 mm), increased wall hyperintensity on T2-weighted images, increased wall gadolinium enhancement on T1-weighted images, perivisceral fat edema or hypertrophy, and local enlarged lymph nodes.	Segments

Table 1 (continued)

Study	Sample size	Age (years, mean or range)	Male (%)	Country	Inclusion	Study aim	Standard of reference	Modality compared with standard of reference	Time gap	Magnet strength or probe frequency	MRE/US diagnostic criteria	Analysis level
Dubron 2016 [19]	48	13 (12–15)	23 (47.9%)	France	Suspected or known IBD	Detection of active lesions on MRE in children with IBD	Histopathological finding	MRE	Within 8 weeks	1.5 T	Graded 2 or 3 for DWI and contrast enhancement images were considered significant for active lesion	Patients
Oliva 2016 [20]	40	13.1 ± 3.1	22 (55%)	Italy	Diagnosed CD	Assessing disease activity of the small bowel and colon in pediatric CD	Ileocolonoscopy; consensus reference standard; Histology	MRE, SICUS	Sequentially over 5 days	NR	US criteria for the presence of small bowel CD lesions were increased wall thickness ($3 mm), 16–18 reported as the average of at least 3 measurements; loss of stratification of the bowel wall; "stiffness," identified as an intestinal loop with increased wall thickness; or distended loop, which remains unchanged during transabdominal compression. The extension of small bowel lesions was reported as the average of at least 3 measurements.	Patients
Tsai 2017 [21]	41	13.7 (range: 4.6–18.9)	22 (53.7%)	USA	Suspected or known CD	Screening evaluation of pediatric CD	US sensitivity and specificity were evaluated using MRE findings of terminal ileitis; MRE sensitivity and specificity were evaluated using final endoscopic and histopathological diagnosis.	US, MRE	Immediately before or after MRE	1.5 or 3 T; high-resolution 5–17 MHz or 5–12 MHz linear transducer; color Doppler was performed with low flow settings and with a velocity scale range of 4.5 cm/s	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.	Patients
Masselli 2019 [22]	68	10.3 (range: 6–16)	30 (44.1%)	Italy	Diagnosed CD	Detection of active small-bowel inflammation in pediatric patients with CD	Histopathological findings	MRE	5.5 days (range 1–21 days).	1.5 T	Pediatric CD activity index (PCDAI)	Patients

CD, Crohn's disease; *IBD*, inflammatory bowel disease; *MRE*, magnetic resonance enterography; *SICUS*, small-intestine contrast US; *SBCE*, small-bowel capsule endoscopy; *US*, ultrasound; *NR*, not reported

Table 2 Quality assessment of included studies based on Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2)

Study	Risk of bias				Applicability concerns		
	Patient selection	Index test	Reference standard	Flow and timing	Patient selection	Index test	Reference standard
Casciani, 2010 [15]	□	□	□	□	□	□	□
Gee 2011 [20]	?	□	□	?	□	□	□
Quencer 2013 [21]	?	□	□	□	□	□	□
Maccioni 2014 [16]	□	□	□	□	□	□	□
Dubron 2016 [17]	□	□	□	□	□	□	□
Oliva 2016 [18]	□	□	□	□	□	□	□
Tsai 2017 [22]	?	□	□	□	□	□	□
Masselli 2019 [19]	□	□	□	□	□	□	□

□: Low Risk □: High Risk ?: Unclear Risk

Statistical analysis

All analyses were performed using MetaDiSc 1.4 (Unit of Clinical Biostatistics, Ramon y Cajal Hospital, Madrid, Spain). Pooled sensitivity, specificity, positive and negative likelihood ratios (PLR and NLR), diagnostic odds ratio (DOR), and the area under the summary receiver operating characteristic curves value (SROC) were combined for statistical analysis. Statistical heterogeneity was evaluated using the chi-square test and the I^2 index. An I^2 index > 50% and Q-test $p < 0.10$ indicated high heterogeneity, and the random-effects model was used; otherwise, the fixed-effects model was used [14]. p values < 0.05 were considered statistically significant. Potential publication bias analysis was not performed because < 10 studies were included in each meta-analysis [14].

Results

Selection of the studies

Figure 1 presents the study selection process. Initially, 155 articles were retrieved from the three databases and 121 articles were left after removing the duplicates. Twenty-three articles were excluded based on the report type, and 98 full-text papers were assessed for eligibility. Eighteen were excluded because of study aim/design, 34 because of the population, 13 because MRE or US was not used for diagnosis, 20 because the reported data could be used to construct at least one 2 × 2 table for test performance, and five for not being published in English. Therefore, eight studies were included in the present meta-analysis (Table 1).

This meta-analysis included 340 children. All patients had either suspected, diagnosed, known, or histologically proven IBD. All eight studies used MRE for diagnosis, and two used US. The studies were from Europe [15, 18–20, 22] and the USA [16, 17, 21]. The reference diagnostic standard was histology [16, 17, 19, 22] or a comprehensive diagnosis based on history, clinical parameters, imaging, and/or histology [15, 18, 20, 21].

The QUADAS-2 tool showed that all studies had low risks of biases, except for Gee et al. [16], Quencer et al. [17], and Tsai et al. [21], for an uncertain risk of patient selection bias, and Gee et al. [16], for an uncertain risk of flow timing bias (Table 2).

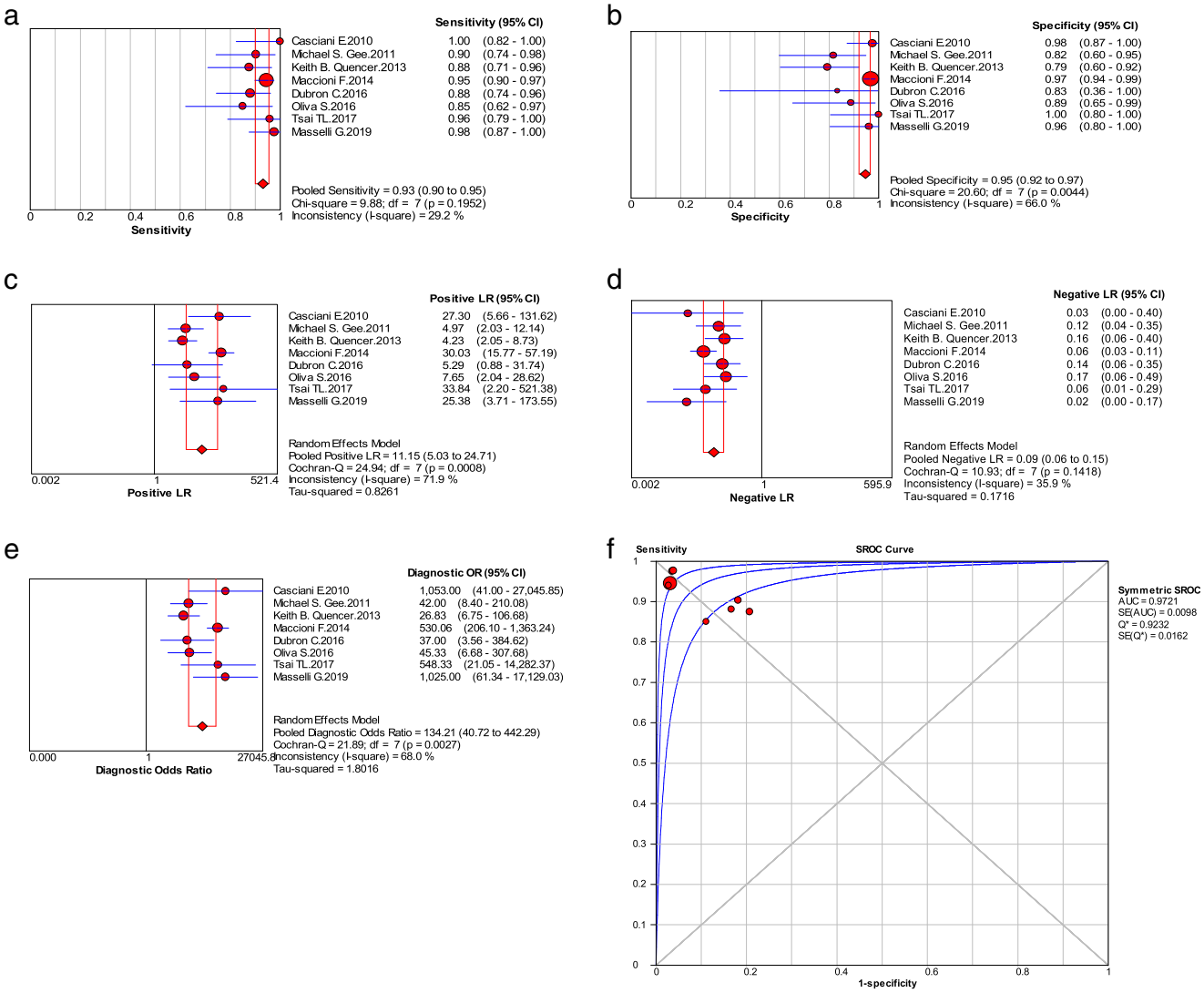

Fig. 2 Overall performance of magnetic resonance enterography (MRE). **a** Pooled sensitivity. **b** Pooled specificity. **c** Pooled positive likelihood ratio (PLR). **d** Pooled diagnostic likelihood ratio (DLR). **e** Overall diagnostic odds ratio (DOR). **f** The area under the summary receiver operating characteristic curves value (SROC).

Overall performance of MRE

All eight studies [15–22] could be included for the analysis of MRE overall performance (irrespective of per-patient/per-segment level). Compared with the reference standard, MRE showed a pooled sensitivity of 93.0% (95% confidence interval (CI): 90.0–95.4%; $I^2 = 29.2\%$, $p_{heterogeneity} = 0.195$), pooled specificity of 94.6% (95% CI: 92.1–96.5%; $I^2 = 66.0\%$, $p_{heterogeneity} = 0.004$), pooled PLR of 11.146 (95% CI: 5.027–24.713; $I^2 = 71.9\%$, $p_{heterogeneity} = 0.001$), pooled NLR of 0.094 (95% CI: 0.057–0.155; $I^2 = 35.9\%$, $p_{heterogeneity} = 0.142$), and pooled DOR of 134.21 (95% CI: 40.72–442.29; $I^2 = 68.0\%$, $p_{heterogeneity} = 0.003$), with a SROC of 0.9721 (Fig. 2).

Performance of MRE at the patient level

Five studies [15, 19–22] could be included for the analysis of MRE performance at the patient level. Compared with the reference standard, MRE had a pooled sensitivity of 93.2% (95% CI: 87.8–96.7%; $I^2 = 48.2\%$, $p_{heterogeneity} = 0.102$), pooled specificity of 95.4% (95% CI: 89.5–98.5%; $I^2 = 13.9\%$, $p_{heterogeneity} = 0.325$), pooled PLR of 13.187 (95% CI: 6.116–28.434; $I^2 = 0.0\%$, $p_{heterogeneity} = 0.471$), pooled NLR of 0.087 (95% CI: 0.036–0.207; $I^2 = 45.5\%$, $p_{heterogeneity} = 0.119$), and pooled DOR of 181.87 (95% CI: 39.81–380.85; $I^2 = 40.1\%$, $p_{heterogeneity} = 0.154$), with a SROC of 0.9778 (Fig. 3).

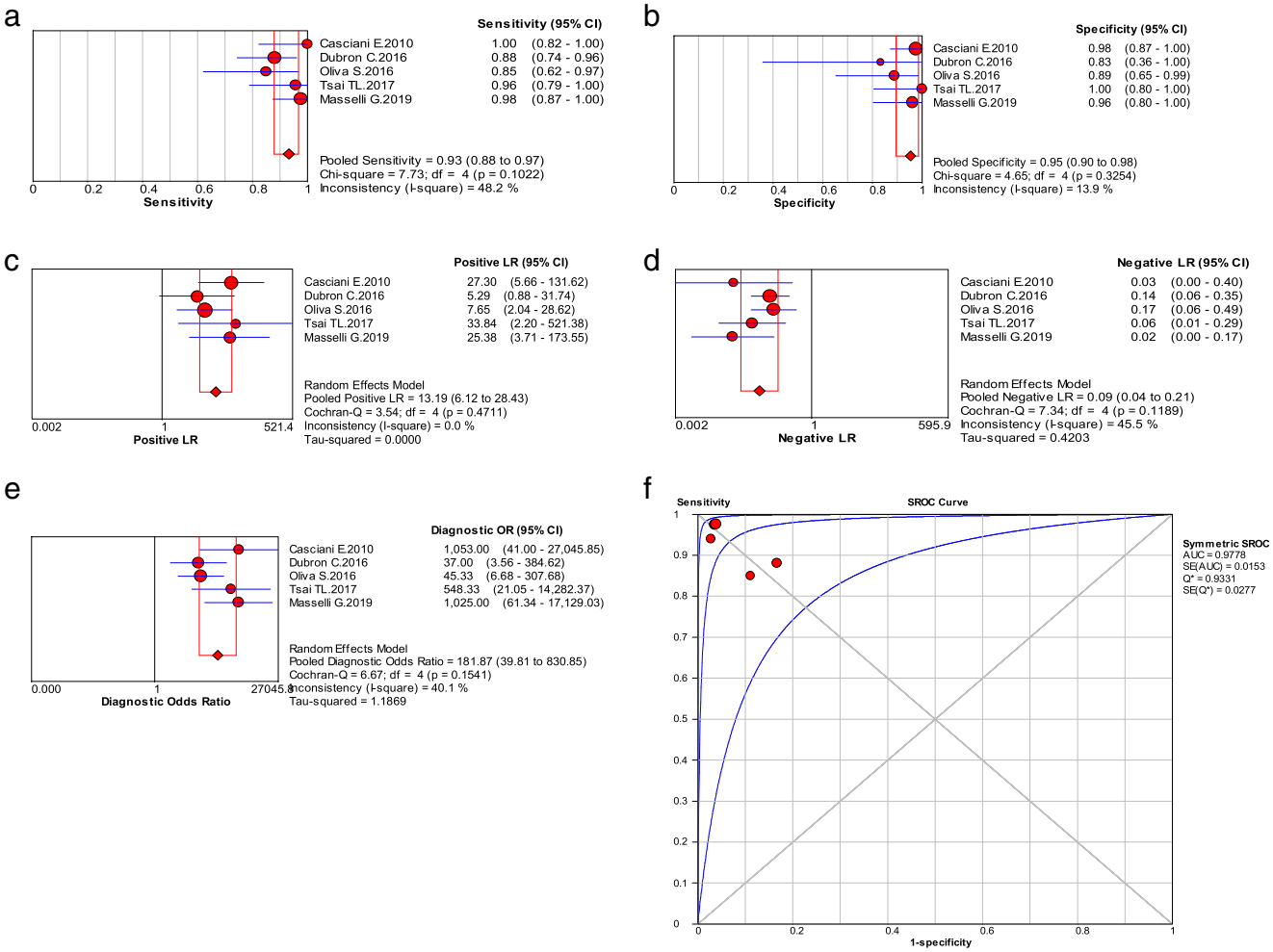

Fig. 3 Performance of magnetic resonance enterography (MRE) at the patient level. **a** Pooled sensitivity. **b** Pooled specificity. **c** Pooled positive likelihood ratio (PLR). **d** Pooled diagnostic likelihood ratio (DLR). **e** Overall diagnostic odds ratio (DOR). **f** The area under the summary receiver operating characteristic curves value (SROC).

Performance of MRE at the segment level

Three studies [16–18] could be included for the analysis of the MRE performance at the segment level (duodenum, jejunum, ileum, ascending colon, transverse colon, descending colon, and rectum). Compared with the reference standard, MRE had a pooled sensitivity of 93% (95% CI: 89–96%; I^2 = 7.0%, $p_{heterogeneity}$ = 0.341), pooled specificity of 94% (95% CI: 91–97%; I^2 = 87.3%, $p_{heterogeneity}$ < 0.001), pooled PLR of 8.72 (95% CI: 2.14–35.44; I^2 = 90.5%, $p_{heterogeneity}$ < 0.001), pooled NLR of 0.09 (95% CI: 0.05–0.19; I^2 = 50.6%, $p_{heterogeneity}$ = 0.132), and pooled DOR of 89.71 (95% CI: 11.41–705.63; I^2 = 86.9%, $p_{heterogeneity}$ < 0.001), with a SROC of 0.9718 (Fig. 4).

Performance of US

Two studies [20, 21] could be included for the analysis of US (reader 2) overall performance. Compared with the reference standard, US had a pooled sensitivity of 84.1% (95% CI: 69.9–93.4%; I^2 = 0.0%, $p_{heterogeneity}$ = 0.319), pooled specificity of 82.9% (95% CI: 66.4–93.4%; I^2 = 0.0%, $p_{heterogeneity}$ = 0.939), pooled PLR of 4.924 (95% CI: 2.351–10.310; I^2 = 0.0%, $p_{heterogeneity}$ = 0.806), pooled NLR of 0.207 (95% CI: 0.103–0.413; I^2 = 0.0%, $p_{heterogeneity}$ = 0.328), and pooled DOR of 25.919 (95% CI: 7.63–88.07; I^2 = 0.0%, $p_{heterogeneity}$ = 0.463). US (reader 1) (Fig. 5) had a lower pooled diagnostic value of 15.26 (95% CI 2.32–100.33; I^2 = 60.7%, $p_{heterogeneity}$ = 0.111) than US (reader 2) (Fig. 6).

Discussion

This meta-analysis aimed to determine the diagnostic performance of MRE and US in pediatric patients with IBD. The results suggest that both MRE (at the patient and segment levels) and US (irrespective of the reader) have good performance in detecting IBD in pediatric patients.

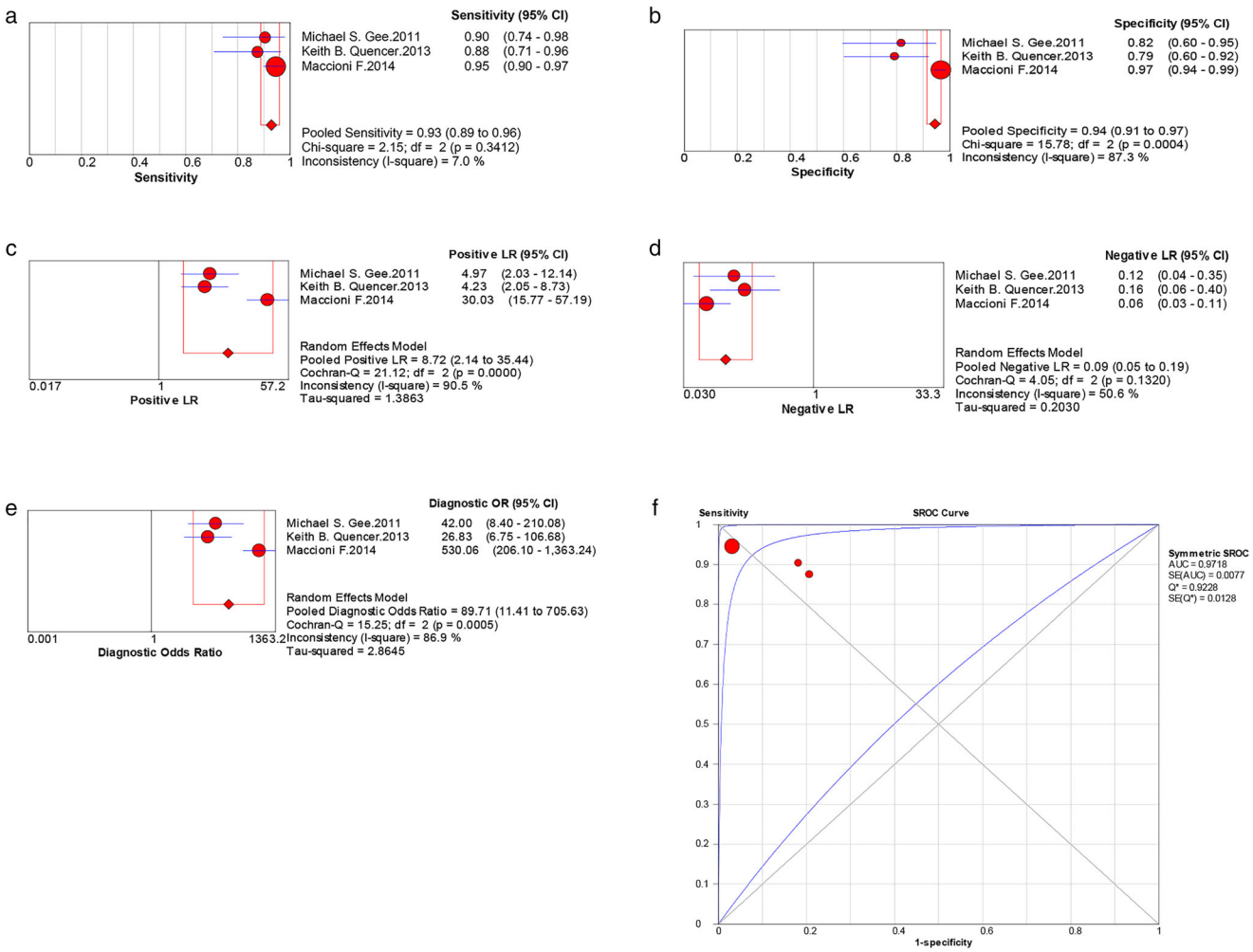

Fig. 4 Performance of magnetic resonance enterography (MRE) at the segment level. **a** Pooled sensitivity. **b** Pooled specificity. **c** Pooled positive likelihood ratio (PLR). **d** Pooled negative likelihood ratio (NLR). **e** Overall diagnostic odds ratio (DOR). **f** The area under the summary receiver operating characteristic curves value (SROC).

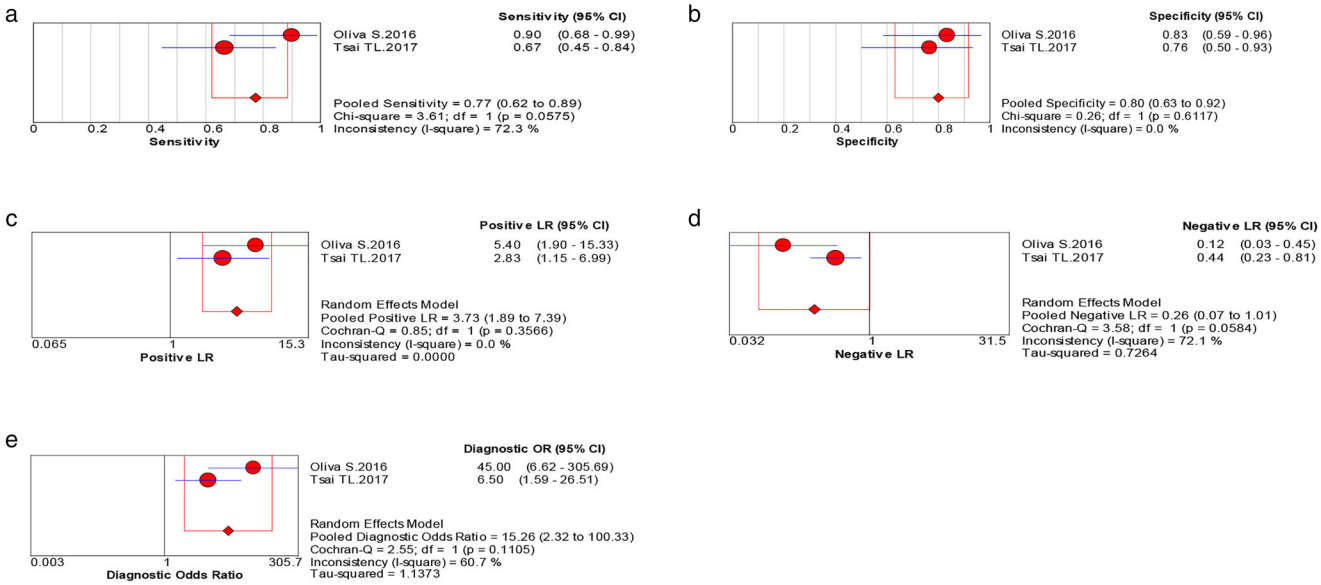

Fig. 5 Performance of ultrasound (US) (reader 1). **a** Pooled sensitivity. **b** Pooled specificity. **c** Pooled positive likelihood ratio (PLR). **d** Pooled negative likelihood ratio (NLR). **e** Overall diagnostic odds ratio (DOR).

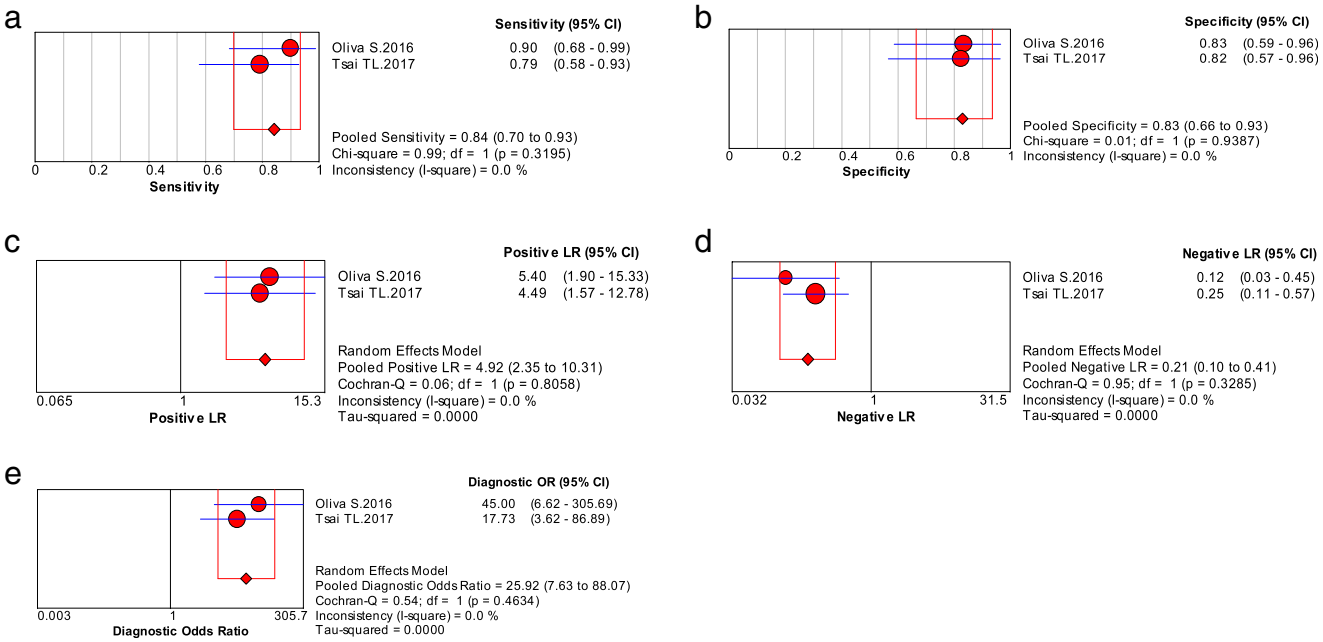

Fig. 6 Performance of ultrasound (US) (reader 2). **a** Pooled sensitivity. **b** Pooled specificity. **c** Pooled positive likelihood ratio (PLR). **d** Pooled negative likelihood ratio (NLR). **e** Overall diagnostic odds ratio (DOR).

Yoon et al. [10] completed a meta-analysis of 18 studies (687 patients) to determine the diagnostic accuracy of MRE. They included any type of study that examined this issue, while the present study included only studies from which a 2 × 2 table could be built, explaining the smaller number of studies in the present meta-analysis, which only included prospective studies. Still, compared with Yoon et al. [10], the present meta-analysis captured one recent paper [22] and one older one [17]. Yoon et al. [10] reported a lower sensitivity (83%) than in the present meta-analysis (93%) but similar specificity (93% and 95%). They observed that the scanner manufacturer influenced the diagnostic value of MRE, but this could not be examined in the present study because of the small number of studies included and a too-large variety of scanners. Nevertheless, the sensitivity and specificity reported here are a little higher than what was reported before (80–88% sensitivity and 81–90% specificity) for MRE for the diagnosis of IBD in children [23, 24], which could be due to the technological improvements in scanners and software, increased experience and awareness of the radiologists, and the inclusion of prospective studies only.

Another factor that could improve sensitivity and specificity is the relatively recent popularization of the use of diffusion-weighted imaging (DWI) [25], in which a restricted diffusion indicates active inflammation [26, 27]. The meta-analysis by Yoon et al. [10] observed that DWI influenced their results, but this could not be observed here because DWI was not always used, or it was not always clear whether DWI was included among the MRE examinations or not. In addition, only one study performed a comparison of MRE with vs. without DWI for IBD. It warrants further studies.

In the present study, the pooled sensitivity and specificity of US were 84% and 83%, respectively, which are lower than in two previous meta-analyses in adults by Fraquelli et al. [28] (88% and 93%) and by Dong et al. [29] (88% and 97%). The variations in diagnostic value could be due to the gold standard being used.

A recent meta-analysis directly compared capsule endoscopy, MRE, and US to determine bowel inflammation and reported no significant differences in diagnostic yield among the three modalities [11]. It is supported by van Wassenaert et al. [12], who could not conclude that US was better than MRE for IBD diagnosis. Nevertheless, in the present study, the sensitivity and specificity of US were lower than that of MRE, but the small number of studies prevented any direct comparison. Future studies will have to examine this. Nevertheless, current guidelines support the use of all three modalities for IBD diagnosis [30]. The examinations in IBD aim to determine the characteristics of the disease, to monitor the mucosal response to treatments, and identify complications as early as possible [31–35], emphasizing the role of imaging in the detection of small bowel IBD, aiding the distinction between CD and UC, and defining disease extent. Nevertheless, MRE and US have different advantages and disadvantages, making the two modalities complementary. Indeed, the two modalities are ionizing radiation-free. US can display the bowel wall but cannot visualize the entire gastrointestinal tract [2, 3, 7]. On the other hand, MRE has

difficulty distinguishing fibrosis from inflammation but can display the entire gastrointestinal tract [2, 3]. In addition, US is recommended as the first-line examination, followed by a complementary one, like MRE [2]. Therefore, those non-invasive, highly accurate, and radiation-free examinations can be used in children with IBD, which are important characteristics because they are likely to undergo re-examination several times in their lifetime.

Meta-analyses should always be considered in relation to their limitations. Heterogeneity is an issue in meta-analyses [14] and was observed for some of the measurements analyzed here, including overall MRE specificity, PLR, and DOR. There was no uniformity in the gold standard used in the different studies. The small number of included studies prevented the analysis of the publication bias and the analysis of the factors that could influence the diagnostic value of MRE for IBD in children. This meta-analysis excluded conference abstracts; including them might have increased the sample size and allowed the publication bias analysis, but the data extracted from conference abstracts are limited, and constructing 2×2 would probably have been impossible. Nevertheless, the PRISMA principle [13] and the meta-analysis principles [14] were rigorously applied. Three of the eight included studies presented an uncertain risk of bias for patient selection. The DOR for MRE was very large because of the small numbers of false-negative in Casciani et al. [15] and the small numbers of false-positive in Tsai et al. [21]. Therefore, for these two studies, statistics were necessary to calculate the DOR. Finally, only two studies of US could be included.

In conclusion, the present meta-analysis determined that MRE has good performance in detecting IBD in pediatric patients. Only two studies used US for the diagnosis of IBD in children, and additional studies are necessary.

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Declarations

Guarantor The scientific guarantor of this publication is Qiong Yao.

Conflict of interest The authors declare no competing interests.

Statistics and biometry No complex statistical methods were necessary for this paper.

Informed consent Not applicable in this study

Ethical approval Institutional Review Board approval was not required because it's meta-analysis.

Methodology

• This meta-analysis was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guidelines

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