Diagnostic Performance of Ultrasound, Computed Tomography Enterography and Magnetic Resonance Enterography in Diagnosis and Activity Control of Inflammatory Bowel Disease In Children: A Systematic Literature Review

Rendimiento diagnóstico de la ultrasonografía, la enterografía por tomografía y la enterografía por resonancia magnética en el diagnóstico y control de la actividad de la enfermedad inflamatoria intestinal en niños. Revisión sistemática de la literatura

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Summary

Introduction: Inflammatory bowel disease (IBD) is a serious problem that generates large morbidity in pediatric patients. There are multiple diagnostic methods that allow for its evaluation, among which the most commonly used being bowel ultrasound (BUS), followed by computed tomography enterography (CTE) and magnetic resonance enterography (MRE). ***Objective:*** To identify the diagnostic performance of BUS, CTE and MRE in the diagnosis and determination of the activity of inflammatory bowel disease in children. ***Methods:*** A systematic review was performed in the following databases: Medline, Embase, Lilacs, Cochrane Database of Sytematic Reviews, Scielo and gray literature with time restriction between 2000 and March 2016 using MeSH terms and restricted to patients under 18 years with a confirmed diagnosis by ileocolonoscopy-histology. Two investigators independently conducted the study quality study through the application of QUADAS-2. Cross-sectional observational studies were chosen that compared one or more of the aforementioned diagnostic tests (BUS, CTE or MRE) against the reference standard. Variables, such as signs of inflammatory bowel involvement (thickening of the intestinal wall > 3 mm), mesenteric extraintestinal involvement (inflammatory changes of mesenteric fat, prominent mesenteric nodes, vasa recta prominence), and increase in bowel wall perfusion with color doppler, were taken into account. ***Results:*** All studies used endoscopy as the reference standard. The sensitivity ranged between 67% and 96% for the BUS and from 60% to 94.5% for the MRE. The specificity ranged between 77.8% and 100% for the BUS and from 80% to 100% in the MRE. The PPV for BUS was 83% to 100% and MRE was 92-94%. Finally, the NPV for BUS was 66.7% to 85% and for MRE it was 84% - 97%. No studies were found for CTE. ***Conclusions:*** Both the MRE and BUS have similar diagnostic performance in the diagnostic suspicion and follow-up of IBD compared to colonoscopy in the pediatric population.

Resumen

Introducción: La enfermedad inflamatoria intestinal (EII) es un serio problema que está generando alta morbilidad en el paciente pediátrico. Existen múltiples métodos diagnósticos que permiten su evaluación, entre los cuales, los más utilizados son el ultrasonido intestinal (US), la enterografía por tomografía computarizada (ATC) y la enterografía por resonancia

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magnética (ERM). ***Objetivo:*** Identificar cuál es el rendimiento diagnóstico del ultrasonido intestinal, la enterografía por tomografía computarizada y la enterografía por resonancia magnética en el diagnóstico y determinación de la actividad de la enfermedad inflamatoria intestinal en niños. ***Métodos:*** Se realizó una revisión sistemática de la literatura en las bases de datos: Medline, Embase, Lilacs, Cochrane Database of Sytematic Reviews, SciELO y literatura gris desde 2000 hasta marzo de 2016, usando términos MeSH y limitada a pacientes menores de 18 años con diagnóstico confirmado por ileocolonoscopia y/o histología de enfermedad inflamatoria intestinal. Dos investigadores independientes realizaron el estudio de calidad mediante la herramienta QUADAS-2. Se eligieron estudios de diseño observacional de corte transversal que compararan una o más de las pruebas diagnósticas mencionadas contra el estándar de referencia. Se tuvieron en cuenta variables como signos de compromiso inflamatorio intestinal (engrosamiento de la pared intestinal >3 mm) y extraintestinal mesentérico (cambios inflamatorios de la grasa mesentérica, ganglios mesentéricos prominentes, prominencia de la *vasa recta*), hiperemia de la pared intestinal en la ecografía Doppler color. ***Resultados:*** Todos los estudios usaron la endoscopia como estándar de referencia. La sensibilidad se encontró en rangos entre 67-96 % para el US y de 60-94,5 % para la ERM. La especificidad se encontró en rangos de 77,8-100 % para el US y de 80-100 % en ERM. El VPP para el US fue de 83-100 % y para la ERM fue de 92-94 %. Por último, el VPN para el US fue de 66,7-85 % y para la ERM fue de 84-97 %. No se encontraron estudios para ETC. ***Conclusiones:*** Tanto la ERM como el US tienen rendimiento diagnóstico similar en la sospecha diagnóstica y en el seguimiento de la EII comparado con la colonoscopia, en la población pediátrica.

1. Introduction

Inflammatory bowel disease (IBD) is a complex pathology of unknown etiology, whose incidence in the pediatric population has progressively increased in both industrialized countries and developing countries. It comprises two main subtypes: Crohn›s disease (CD) and ulcerative colitis (UC); a third less frequent subtype corresponds to indeterminate colitis (IC). The prevalence in the United States is estimated at approximately 40 per 100,000 children for CD and 28 per 100,000 children for UC (1).

The diagnosis and treatment of IBD is multidisciplinary and requires clinical, laboratory, imaging, endoscopic and histological criteria. The imaging method traditionally used for the diagnosis of IBD has been intestinal transit with barium; However, implementation of innovative studies, such as ultrasound (US) intestinal high-resolution computed tomography enterography (CTE) and magnetic resonance enterography (MRE) allow to assess not only the lumen but the mural and extraintestinal compromise of the IBD with a better accuracy of the findings (2).

The intestinal transit has good diagnostic performance in the evaluation of the intestinal lumen, with a sensitivity and specificity of 90 and 96% respectively, in the diagnosis of CD in the terminal ileum (3). Among its limitations are the use of ionizing radiation and the poor evaluation of extraintestinal compromise, which has led it to occupy a secondary role in the study of this entity. The US is a non-invasive, inexpensive and readily available diagnostic modality which allows to observe characteristics of the intestinal wall such as thickening (> 3 mm), alteration of stratification (loss of the 5 layers of the intestinal wall), extraintestinal alterations and the assessment of active inflammation with color Doppler (4).

CTE and MRE are methods that use a negative enteric contrast medium to distend the intestinal loops and improve their characterization. Additionally, the two techniques allow evaluation of the extraintestinal involvement of IBD: congestion of the vasa recta or «comb sign», inflammation of the mesenteric fat adjacent to the intestinal loops and prominent lymph nodes (signs of inflammatory activity) (5, 6). They also allow findings such as stenosis, polyps, adhesions, fistulas, abscesses and phlegmons. The CTE has as advantages: the wide availability in the hospital environment, sedation is not required, the study time is short and the resolution of the image is good; however, the use of ionizing radiation has limited its use in the pediatric patient. Its use is preferred in certain clinical scenarios, such as the suspicion of IBD and acute complications of the disease (abscesses and intestinal perforation, among others), which require surgical management (7).

MRE has the advantage of not using ionizing radiation, it allows to characterize perianal disease, the formation of fistulas (8, 9) and to differentiate the state of the disease (acute versus chronic); it is characterized as active when the following findings are observed: thickening of the intestinal wall, high signal of the wall in T2-STIR (sequence-short tau inversion recovery) and wall enhancement after administration of the contrast medium in enhanced sequences in T1 (10). Additionally, it allows obtaining dynamic images that facilitate the assessment of intestinal peristalsis of the involved segments (5). Its main disadvantages are the prolonged time for the acquisition of the images, the loss of image quality due to movement artifacts and the requirement of sedation in children under 8 years of age.

Due to the need to make an accurate diagnosis in the pediatric patient with the application of the best diagnostic imaging method available, the objective of this study is to identify the diagnostic performance of the intestinal US, the CTE and the MRE in the diagnosis and determination of the activity of IBD in children.

2. Metodology

The research question was: What is the diagnostic performance of the US, the CTE and the MRE in the diagnosis and determination of the activity of IBD in children? We searched for results in sensitivity,

specificity, positive predictive value (PPV) and negative predictive value (NPV) compared to the reference standard (ileocolonoscopy and / or histology).

A systematic search was developed from 2000 to March 2016, with language restriction (English and Spanish) in the following databases: Medline, Embase, Lilacs, Cochrane Database of Sytematic Reviews, SciELO and gray literature. The MeSH terms used were: *Inflammatory Bowel disease, Crohn's disease, Crohn's disease, Crohn's enteritis, terminal Ileitis, Idiopathic proctocolitis, ulcerative colitis, Children, child, pediatric, Ultrasound imaging, imaging, ultrasound, ultrasonic diagnosis, medical sonography, echography, Doppler ultrasonography, Multidetector computed tomography, Multisection computed tomography. Multislice computed tomography, Imaging magnetic resonance, MRI scan*.

Once the studies were obtained, the duplicates were eliminated and two researchers trained in Radiology evaluated the potential articles. The inclusion criteria were the following:

- ***Types of studies:*** Observational design studies, cross-sectional, comparing one or more of the aforementioned diagnostic tests (US, CTE or MRE) against the reference standard (ileocolonoscopy-histology). Meta-analyzes, systematic reviews of the literature, cohort studies and case series were included.
- ***Types of participants:*** Studies with more than 10 patients with an age range between 0 and 18 years of age, with IBD confirmed by endoscopy or histopathology, with and without symptoms suggestive of activity.
- ***Diagnostic studies:*** US, CTE and MRE. Diagnostic studies performed simultaneously or with a time of less than 15 days to the completion of the reference standard.
- ***Findings-variables found:*** Signs of inflammatory bowel involvement (thickening of the intestinal wall> 3 mm) and extraintestinal (inflammatory changes of mesenteric fat, prominent mesenteric nodes, vasa recta prominence), hyperemia with Doppler vascularization.
- ***Reference standard:*** The definitive diagnosis of IBD is made by adding several criteria; however, the literature has taken the endoscopic and histological results as the reference standard for both diagnosis and activity of the disease.

The exclusion criteria were the following:

Studies that include a population older than 18 years, studies performed without a protocol of CTE or MRE, patients who have received treatment for IBD during the time of application of the diagnostic test and the reference standard.

The included articles were assessed using the QUADAS 2 (Quality Assessment of Diagnostic Accuracy Studies) tool.

2.1 Statistical analysis

With the online application of QUADAS-2 of the Rheumatology Group of the Universidad Nacional de Colombia, the risk of bias and the applicability of the articles were evaluated (10,11). The data collection and statistical analysis was developed in Excel 2011.

The prevalence of the radiographic findings and the analysis of the data were synthesized using the software Comprehensive meta-analysis version 3.0 (12).

2.2 Ethical responsibilities

The authors declare that no experiments were carried out on humans or animals and patient data were not used for this research, as stipulated in the Declaration of Helsinki.

3. Results

864 articles were found and were selected by title or summary 246, which were reviewed. Of these, 217 articles were excluded for the following reasons: inclusion of patients over 18 years of age, there was no comparison with the reference standards determined, the abstracts did not include sufficient information to perform the analysis, the authors did not include a cut-off point of the intestinal wall to determine normality or abnormality, the diagnostic test was performed more than 15 days apart from the reference standard and vice-versa, and review articles.

There were 29 articles that were submitted to risk assessment of bias using the tool QUADAS-2. Finally, 6 articles were evaluated, which included 267 patients (128 with CD, 83 with UC, 12 with IC, and 44 controls). The age group is similar in all the studies, with ranges between 2 and 18 years with greater affectation between the group of 6 and 18 years. No significant differences were found between boys and girls.

The selected studies were published between 2003 and 2014, and the largest number of patients included 75 children. All the included patients were evaluated by at least one diagnostic modality: 95 by US, 125 by MRE and 47 by both methods (Table 1). No studies were obtained in which the performance of the CTE was evaluated, since they were not compared with the reference standard or were performed without an enterography protocol. The ileocolonoscopy was used as the reference standard in all the studies and, of these, two compared the results with ileocolonoscopy and histology.

3.1 Study design and methodological quality

All the studies were performed prospectively. Their quality was very homogenous and low risk, with scores of QUADAS-2 from 10 to 13 out of 13 (Table 2). The following articles were classified as intermediate risk: Dilillo (13), Laghi (14), Civitelli (15) and Aloi (16). All those that gave high risk of bias in one or more domains were excluded (Figure 1).

Table 1. Basic information of the studies included in the review

Study author	Diagnosis / Number and characteristics of evaluated patients	Reference standard	Diagnostic method used	Diagnostic criteria used
Civitelli 2014 (15)	50/50 UC Age: 2-18 years M: 23 F: 27	Colonoscopy	US	Thickening of the wall> 3 mm. Secondary findings: Vascularization of the wall with color Doppler, loss of haustration, absence of stratification (loss of 5 layers), prominent lymph nodes.
Berni 2005 (18)	45/45 27 IBD Edad: 11-14 años M: 12 F: 15	Colonoscopy histology	US	Thickening of the wall of 3 mm or more measured in transverse and longitudinal plane.
Dilillo 2014 (13)	13/13 IBD: 7 CD 5 UC 1 SI Age: 7,7-17,5 years.	Ileocolonoscopy	US, MRE	Thickening of the intestinal wall greater than 3 mm.
Aloi 2015 (16)	34/34 CD: 28 Suspicion CD: 6 Age: 12,1±4,5 years. M: 18 F: 10	Ileocolonoscopy	US-MRE	US: thickening of the wall ≥ 3 mm. Loss of stratification of the wall, non-compressible handles. MRE: Thickening of the wall> 3 mm, enhancement of the wall of the SI with the contrast medium, increase of the signal of the wall in T2, stratification of the wall with the contrast medium in T1 with suppression of fat.
Laghi 2003 (14)	75/75 Active CD: 26 Active UC: 18 IC: 11. 20 controls. Age: 8-17 years	Colonoscopy histology	MRE	Thickening of the wall> 3 mm. Enhancement of the wall with contrast medium.
Maccioni 2014 (17)	50/50 50/50 All with CD. Age: 6-18 years M: 26 F: 24	Ileocolonoscopy	MRE	Engrosamiento concéntrico de la pared > 4 mm. Concentric thickening of the wall> 4 mm. Increase of the intensity of the wall in T2, increase of the enhancement with gadolinium in T1. Edema of perivisceral fat, hypertrophy, prominent local ganglia.

Abbreviations: US: ultrasound, MRE: magnetic resonance enterography, UC: ulcerative colitis, CD: Crohn's disease, IC: Indeterminate colitis, IBD: Inflammatory bowel disease, SI: small intestine.

Table 2. Summary of studies according to QUADAS II score classification including sensitivity data, specificity and authors' comments

Study	QUADAS II score	Diagnostic modalities	Conclusions
Civitelli, 2014 (15)	12/13	US	Right colon S 75 % (CI 95 % 42-93) Sp 100 % (CI 95 % 74-100) PPV 100 % (CI 95 % 62-100) NPV 83 % (CI 95 % 57-98 %) Transverse colon S 86 % (CI 95 % 60-97) Sp 100 % (CI 95 % 70-100) PPV 100 % (CI 95 % 71-100) NPV 85 % (CI 95 % 56-97 %) Left colon S 96 % (CI 95 % 80-100) Sp 100 % (CI 95 % 62-97) PPV 100 % (CI 95 % 83-100) NPV 80 % (CI95 % 30-100 %)

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Continuation

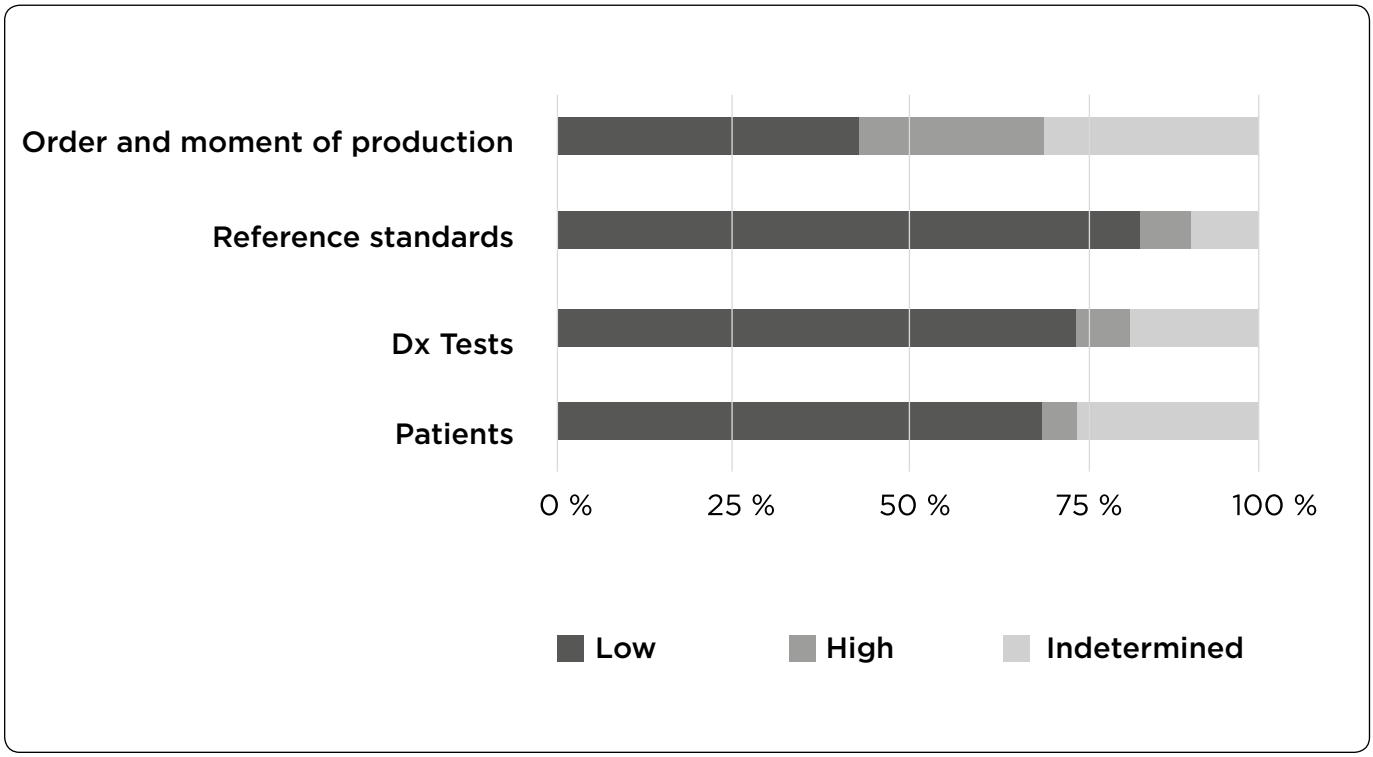
Berni, 2005 (18)	13/13	US	S 74.1 % (CI95 % 53.7-88.9) Sp 77.8 % (CI95 % 52.4-93.6) PPV 83.3 % (CI 95 % 62.6-95.3) NPV 66.7 % (CI 95 % 4-85.4)
Dilillo, 2014 (13)	12/13	US and MRE	**Overall performance** US S 67 %. Sp 100 % MRE S 60 %. Sp 97 % **By segments** Terminal ileum US S 86 %. Sp 100 % MRE S 100 %. Sp 100 % Blind US: S 64 %, E 100 % MER: S 55 %, E 100 % Ascending colon US: S 60 %, E 100 % MRE: S 60 %, E 100 % Transverse colon US: S 67 %, E 100 % MRE: S 56 %, E 100 % Descending colon US: S 75 %, E 100 % MRE: S 63 %, E 100 % Sigmoid US: S 75 %, E 100 % MRE: S 63 %, E 80 % Rectum US: S 43 %, E 100 % MRE: S 29 %, E 100 %
Aloi, 2015 (16)	12/13	US and MRE	Terminal ileum Contrasting US of small intestine S 94% (64-100). Sp 79% (49-95). NPV 91% (61-100). PPV 85% (62-96) MRE S 94% (71-100). Sp 80% (51-96). NPV 92% (64-100). PPV 84% (60-97)
Laghi, 2003 (14)	11/13	MRE	In 26 (CD) patients MRE was abnormal in the distal ileum. MRE did not reveal involvement of the small bowel proximal to the terminal ileum in any patient with CD. 15 patients with UC were negative in MRE. mild wall enhancement in 3 of 7 patients with backwash ileitis. Terminal ileum S 84 %. Sp 100 %
Maccioni, 2014 (17)	13/13	MRE	General -S 94.5 %. Sp 97 %. PPV 94.5 %. NPV 97 % Total small intestine - S 97 % (91-100). Sp 98 % (89-100). PPV 95 % (87-100). NPV 99 % (86-100) Total colon - S 93 % (87-97). Sp 96 % (93-99). PPV 94 % (89-98). NPV 95 % (91-98) By segments Jejunum- S 88 % (65-100). Sp 97 % (90-100). PPV 88 % (65-100). NPV 97 % (90-100) Proximal and middle ileum S 100 (57-100). Sp 97 % (87-100). PPV 85 % (44-97). NPV 97 % (91-100) Distal ileum - S 100 % (87-100). Sp 100 % (82-100). PPV 100 % (87-100). NPV 100 % (82-100) Blind - S 93 % (62-96). Sp 100 % (88-100). PPV 100 % (77-100). NPV 97 % (79-98) Ascending colon - S 70 % (41-93). Sp 97 % (90-100). PPV 87 % (61-100). NPV 92 % (82-99) Ascending colon - S 80 % (53-98). Sp 100 % (90-100). PPV 100 % (65-100). NPV 95 % (86-100) Descending colon - S 100 % (85-100). Sp 92 % (72-97). PPV 92 % (73-98). NPV 100 % (84-100) Sigmoid colon - S 96 % (80-99). Sp 90 % (75-99). PPV 93 % (80-99). NPV 95 % (75-99) Rectum - S 96 % (82-99). SpE 88 % (62-96). PPV 94 % (78-98). MPV 94 % (69-99)

3.2 Ethical considerations of the studies

Two studies used ultrasound only as a diagnostic test, two used US and MRE and two used MRE alone. Of the four studies that used the US only two performed bowel preparation that included the 6-hour fast prior to the examination.

Aloi (16) performed bowel preparation with a 6-hour fast and later ingestion of a solution of polyethylene glycol diluted in water with imaging every 15 minutes. The frequency of the transducers used was similar, except in Dilillo (13), which does not specify the characteristics of the equipment and Aloi (16) that used a linear transducer of lower frequency (5 MHz).

Figure 1. Evaluation of the risk of bias and applicability



As for the studies that used MRI, one does not specify the characteristics of the type of resonator used and two do not give information on the sequences used. In the other 1.5 T resonators were used.

Three studies used intestinal preparation with polyethylene glycol as oral negative contrast medium with an average dose of 10 ml / kg. On the other hand, in one study an additional medication was used, in order to decrease peristalsis and prolong distension (hyoscine butylbromide, 10 mg IV) (17). The sequences used in most of the studies were enhanced in T2 with FSE (Fast Spin Echo) with and without fat suppression and T1 with fat suppression and application of intravenous contrast medium (gadolinium, with doses of 0.1 mmol / kg). Some studies included additional sequences, such as T1 with gradient echo (17).

The main finding to determine compromise due to IBD was thickening of the bowel wall> 3 mm. Other findings described by the authors for the US were increased vascularization of the wall with color Doppler, loss of haustration, lack of wall stratification and prominent lymph nodes (15,16,18) (Table 3).

Additional signs described for MRE were wall edema (increased signal intensity at T2, compared to an adjacent healthy intestinal loop), stratified appearance of the wall ("target sign") on T1 images with medium contrast, stenosis, narrowing of the lumen less than 10 mm, "comb sign" (increased vascularity adjacent to the inflamed intestinal loop) reactive mesenteric lymph nodes and extraintestinal complications (fistulas, abscesses, and intraperitoneal fluid) (14,16,17).

3.3 Performance assessment (sensitivity, specificity, PPV and NPV) of the US and MRE for IBD in children

All the included studies gave information on sensitivity, specificity, PPV and NPV, except in two studies that only reported the first two.

Colonoscopy was taken as a reference standard, although during the search the histopathological report was considered as part of the standard, together with the colonoscopy.

The radiological criterion common to all the studies and with which the comparison was made was the thickening of the intestinal wall> 3 mm.

The sensitivity was found in ranges between 67-96% for the US and 60-94.5% for the MRE. The specificity was found in ranges between 77.8-100% for the US and 80-100% in the MRE. The PPV for the US was 83-100% and for the MRE it was 92-94%. Finally, the NPV for the US was 66.7-85% and for the MRE it was 84-97% (Table 4).

The general performance values given by each article were taken; however, these values may vary in the same study according to the segment evaluated, as is discriminated in Table 3. It is important to highlight, with respect to the values of MRE, that in the studies of Aloi (16) and Laghi (14) only the terminal ileum was taken into account, therefore the performance data of these studies can not be generalized to the other intestinal segments (Table 4).

Table 3. Summary of the technical aspects used in the reported diagnostic methods

Study	Equipment characteristic	Transducer	Sequence	Bowel preparation	Contrast	Observers
Civitelli, 2014 (15)	Aplio X6 Toshiba	Convex 3,5-5 MHz Lineal 7,5-12 MHz	----	6 hours of fasting	No	One observer
Berni, 2005 (18)	Logic 500. General Electric	Convex 5 MHz Linear 7,5-12 MHz	----	Any	No	One observer
Dilillo, 2014 (13)	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified
Aloi, 2015 (16)	Aplio XG. Toshiba	Convex 3,5 MHz and linear de 5 MHz	----	Fasting 6 hours	- Ingestion of 125 to 250 ml of PEG solution diluted in water. - Evaluation with interval every 15 minutes.	One observer (sonographer dedicated to intestine).
	Siemens 1.5 T with 8 channels and abdominal phase antenna.	----	Not specified	Dosage of hyoscine butylbromide, 10 mg IV, decreases peristalsis and prolongs distension.	Use of PEG as oral negative contrast. Intravenous contrast medium Gadolinium (Magnevist) 0.1 mmol / kg	One observer (radiologist).
Laghi, 2003 (14)	Magnetom Vision Plus. Siemens 1,5 T.	-----	T2w (HASTE) T1w with SG (FLASH)	Fasting from the previous night.	PEG solution 10 ml / kg. - Not antispasmodic - Gadolinium (Magnevist) 0.1 mmol / kg	Consensus of two expert radiologists.
Maccioni, 2014 (17)	Magnetom Avanto, Siemens. 1,5T Antena de 16 canales.	----	T2w FSE-SSTSE with and without SG. T2w radial TSE T1w GE T2w HR TSE with and without SG.	Fasting of 8 hours.	45 minutes before the study, superparamagnetic solution (silicon particles covered with iron) was given. Dosage: 200-700 ml (10 mL / kg). Gadolinium IV (Dotarem) Dose 0.1 mmol / kg.Dosis: 200-700 ml (10 mL/kg). Gadolinio IV (Dotarem) Dosis 0,1 mmol/kg.	Consensus of two expert radiologists.

Table 4. Summary of values of sensitivity, specificity, positive predictive value and negative predictive value for US and MRE in children with IBD.

Author	Diagnostic modality	Sensitivity	Specificity	PPV	NPV
Civitelli, 2014 (15)	US	75-96 %	100 %	100 %	80-85 %
Berni, 2005 (18)	US	74,1 %	77,8 %	83,3 %	66,7 %
Dilillo, 2014 (13)	US	67 %	100 %		
	MRE	60 %	97 %		
Aloi, 2015 (16)	US	94 %	79 %	91 %	85 %
	MRE	94 %	80 %	92 %	84 %
Laghi, 2003 (14)	MRE	84 %	100 %		
Maccioni, 2014 (17)	MRE	94,5 %	97 %	94,5 %	97 %

3.4 Meta-analyzes

It was not possible to perform a meta-analysis because of the following: having less than 5 studies of the same diagnostic modality to analyze; the heterogeneity of the studies, since they evaluate different intestinal segments; and for presenting intermediate statistical heterogeneity in MRE studies.

4. Discussion

The use of non-invasive methods, such as diagnostic imaging, in the evaluation of IBD in the pediatric patient, becomes a great advance in the diagnosis and control of this disease. US and MRE are useful tools in the intestinal and extraintestinal evaluation of children with CD and UC with adequate diagnostic performance; In addition, they have the advantage of not using ionizing radiation. Despite obtaining an adequate assessment with CTE, this technique is limited in the pediatric patient by exposure to ionizing radiation, it is only used in children with suspected complications, such as abscesses.

Properly assessing the extent and activity is of great importance to define medical or surgical management. Colonoscopy is considered as the reference standard; however, this is an invasive technique, it does not allow to identify the extraintestinal compromise, in patients with severe states of the disease represents a procedure with high risk of complications and, by the chronic course of the disease, multiple colonoscopies are required which is uncomfortable especially for this age group (15).

In this systematic review of the literature, we found six articles on the use of US, CTE and MRE in pediatric patients with IBD who met the inclusion and exclusion criteria. The studies reported good performance for the US and the MRE. No studies with CTE that met the criteria were found.

Among the imaging findings of IBD, the most diagnostic and common in the two diagnostic modalities is the thickening of the intestinal wall ≥ 3 mm. In the US, other signs were identified, such as hyperemia at color Doppler assessment, which has been described as a sign of disease activity; however, there are different ways described to evaluate the degree of activity, quantitatively according to the pixels per square centimeter of intestinal wall (19) or qualitative, by the existence or not of colored pixels in the intestinal wall (15). Alteration of intestinal wall stratification, prominent mesenteric lymph nodes and loss of haustration have been described as associated findings; however, the sensitivity and specificity of these findings in IBD has not been determined (15).

The US is a useful technique that allows to accurately assess the intestinal wall. Civitelli (15) discriminates the performance of the US in all segments of the colon in patients with UC, describes different performance according to the intestinal segment involved. The rectum is the segment that represents the greatest difficulty for its characterization (15, 20) and lower performance, with a sensitivity of 43%, as described by Dilillo (13). Additionally, it is described that the activity and severity of the disease, according to the thickness of the wall, does not allow to differentiate between normal or mild and moderate or severe, that is, intermediate degrees, but it does allow differentiating between the mild and severe compromise (15).

With regard to MRE, the sensitivity reported is between 60-94.5%, specificity between 80-100%, PPV between 92-94% and NPV between 84-97%. Although technical limitations have been reported to evaluate the small intestine, Maccioni (17) mentioned sensitivity, specificity, PPV and NPV of 97%, 98%, 95% and 99%, respectively, for its assessment.

Additionally, in a systematic review of the literature evaluating the performance of small intestinal MRE in patients with CD, a global sensitivity of 84% and a specificity of 97% were reported (21). Of the segments of the small intestine, the best performance for evaluation was the terminal ileum, with sensitivity between 84-100% and specificity between 80-100% (15,17,19). Several authors have described that the differentiation between UC and CD is not possible through the US and MRE, except in cases in which there is involvement of the terminal ileum, associated more frequently with CD (22).

Other findings described for MRE are wall edema in T2-weighted images, mesenteric lymphadenopathy (23, 24) and wall enhancement, after the administration of contrast medium (gadolinium) in the T1-weighted images, with a sensitivity of this last finding of 57% and a specificity of 100% (10).

It is important to take into account at the moment of analyzing the performance of the MRE, that this can be affected by the specific intestinal preparation of both the small intestine and the colon. In order to correctly interpret the images, adequate distension of the intestinal loops is necessary, because an insufficiently distended or collapsed loop can lead to a false thickening of the wall, as well as the diagnosis and estimation of the degree and length of the wall stenoses (17,23,25).

In the case of CT, Jamienson and colleagues (26) found in their study a sensitivity of 86% and specificity of 100%, performance similar to MRE; however, this work was not included in the systematic review because it was not performed with enterography protocol. The use of this technique is limited in pediatric patients by exposure to ionizing radiation and is only considered in specific situations already mentioned (7).

The US is an accessible diagnostic technique, inexpensive, does not require sedation (27) and is available in most of the country's health institutions; however, it has the limitation of being operator-dependent. On the other hand, MRE allows a better evaluation of the small intestine, with better contrast resolution, assessment of functional images and low frequency of adverse reactions to the contrast medium; However, it has limited availability and requires the use of sedation and / or general anesthesia in children under 10 years of age, due to the need for long-term stillness and the low tolerance to this requirement in this age group (6), which increases the costs and the possibility of adverse events of this diagnostic method.

This systematic review has two limitations: the small number of included studies, given that the vast majority of published articles were considered to be at high risk of bias, and the restriction of the search to only articles in Spanish and English

5. Conclusions

Both the MRE and the US have similar diagnostic performance in the diagnostic suspicion and in the follow-up of IBD compared to colonoscopy, in the pediatric population.

The US has good performance and could be considered as the first line study for the diagnosis of IBD, particularly in those patients in whom serious illness is suspected and where colonoscopy is not

available or difficult to perform. Likewise, it is useful in the short-term follow-up of patients to assess the response to medical treatment.

MRE with adequate intestinal distention has good performance to identify the involvement of IBD in thin and thick intestinal loops. Unlike CTE, it does not require the use of ionizing radiation and has an adequate resolution of contrast that allows assessing the intra and extraintestinal involvement of the disease. It is suggested as a complement when the US does not allow adequately characterizing the extent of the disease and the follow-up after treatment.

The CTE should be limited in the pediatric population with IBD, by the use of ionizing radiation, in cases of initial diagnostic suspicion and acute complications, such as fistulas or abscesses or when MRE is not available.

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