



# Is magnetic resonance imaging a viable alternative to ultrasound as the primary imaging modality in the diagnosis of paediatric appendicitis? A systematic review



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## ABSTRACT

**Background:** Appendicitis is the most common cause of acute abdominal pain requiring surgical intervention in paediatric patients. Ultrasound is generally the diagnostic imaging modality of choice, followed by CT, where paediatric appendicitis is suspected. However, high operator dependency and diagnostic restrictions related to anatomical and clinical presentation may limit consistency of application. This paper explores whether MRI is a viable alternative to ultrasound as the primary imaging modality.

**Method:** A systematic review of the literature was undertaken. A search of Medline, Cinahl, PubMed Central and Google Scholar was undertaken supplemented by a review of reference lists, author searching and review of NICE evidence base for existing guidelines. Included studies were assessed for bias using the QUADAS-2 quality assessment tool and data were extracted systematically using a purposefully designed electronic data extraction proforma.

**Results:** Seven studies were included in final review. The age range of participants extended from 0 to 19 years. Only one study with a patient age range of 0–14 used sedation. Sensitivity estimates from the included studies ranged from 92% to 100% while specificity ranged from 89% to 100%. A significant variation in the number and type of sequences was noted between the studies.

**Conclusion:** MRI offers high sensitivity and specificity comparable to contrast enhanced CT and greater than ultrasound as reported in the literature. Where accessibility is not a restriction, MRI is a viable alternative to ultrasound in the assessment and diagnosis of paediatric appendicitis. Clinical practice recommendations have been provided to facilitate the translation of evidence into practice.

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## Introduction

Appendicitis is defined as the inflammation of the vermiform appendix, often as a consequence of bacterial aggregation, resulting in the appendix becoming inflamed and pus filled.<sup>1–3</sup> Appendicitis is the most common cause of acute abdominal pain requiring surgical intervention in paediatric patients.<sup>4–6</sup> The global incidence of appendicitis in children increases from 1 to 2 cases per 10,000 children aged less than 4 years to 25 cases per 10,000 in children between the ages of 10 and 17 years.<sup>7</sup>

In the United States of America, the annual incidence of appendicitis is 37 cases per 10,000 children aged between 0 and 14 years<sup>8</sup> with approximately 70,000 cases reported among all American children annually.<sup>9</sup> In the United Kingdom, acute appendicitis accounts for an estimated 34,000 hospital admissions among the general population with 20% of these cases (approximately 6800) reported to be in children of 0–14 years of age.<sup>10</sup>

The diagnosis of acute appendicitis can be very challenging. In adults, appendicitis often presents with a typical progression of symptoms: periumbilical pain progressing to nausea, right lower quadrant pain and eventually vomiting and fever.<sup>11,12</sup> As a result, successful diagnosis can often be made on presenting clinical features and results of laboratory tests (e.g. Total Leukocyte Count (TLC), C-reactive protein; neutrophil count).<sup>11,13–15</sup> In children, appendicitis may not present with such typical symptoms.<sup>11,12</sup>

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Instead, while childhood appendicitis may present initially with periumbilical pain, symptom progression may lead to flatulence, bowel irregularity/diarrhoea, indigestion, and general malaise.<sup>16</sup> Consequently, a substantial proportion of paediatric appendicitis cases may be misdiagnosed if clinical decision making is based on physical examination, symptoms and laboratory investigations alone.<sup>17</sup> To prevent misdiagnosis and reduce negative appendectomy rates, imaging has been recommended as part of the diagnostic pathway.<sup>16</sup>

Ultrasound (US) is generally the diagnostic imaging modality of choice where paediatric appendicitis is suspected as it is: readily available; has no radiation risk; is relatively fast; and, in comparison to other cross-sectional imaging modalities, is relatively inexpensive.<sup>18</sup> High sensitivity (88%: 95%CI[86–90]) and specificity (94%: 95%CI[94–96]) have also been documented for US in the assessment of paediatric appendicitis.<sup>18,19</sup> However, the focussed nature of ultrasound assessment limits its contribution in determining alternative causes of presenting symptoms<sup>20</sup> and operator dependency remains an acknowledged fundamental limitation.<sup>18</sup> Further, the accurate diagnosis of appendicitis using US may be restricted as a consequence of bowel gas or distension, patient obesity and a retro-caecal (deeply situated) appendix.<sup>21</sup>

Computed Tomography (CT) has previously been considered the main alternative to US and has a high sensitivity and specificity in the diagnosis of appendicitis with much reduced operator dependency.<sup>21</sup> A meta-analysis by Doria et al. (2006)<sup>19</sup> compared CT and US in the diagnosis of appendicitis and determined that in the diagnosis of paediatric appendicitis, the evidence reviewed suggested that CT had a pooled sensitivity of 94% (95%CI: 92 to 97) and a pooled specificity of 95% (95% CI: 94 to 97). However, CT also presents a far greater risk of harm to the child from exposure to ionising radiation and reaction to intravenous contrast media.<sup>22</sup> As a result, the trend is not to refer paediatric patients for CT where appendicitis is suspected.<sup>22</sup>

Magnetic Resonance Imaging (MRI) has been successfully adopted in the assessment of appendicitis in pregnant women offering high soft tissue contrast without the use of radiation.<sup>20</sup> However, long examination times and limited clinical availability have been cited as major limitations to the wider application of MRI in the assessment of acute clinical conditions requiring timely decision making.<sup>20</sup> In addition, long examination times and movement restriction requirements previously meant that sedation of children may have been considered necessary to reduce anxiety and optimise MRI (and perhaps CT) imaging outcomes. Today, the greater accessibility to MRI within the clinical radiology setting globally, and the development of new and faster imaging sequences, reduces the impact of these concerns when identifying MRI as the diagnostic imaging modality of choice. As a result, it is time to consider whether MRI should be considered a viable alternative to ultrasound as the primary imaging modality in the assessment of paediatric appendicitis. This paper reports the findings of a systematic review of the research evidence and considers whether MRI should form part of the diagnostic pathway where paediatric appendicitis is suspected and explores the optimal diagnostic scan sequences to reduce examination time. No previously published systematic reviewed has explored the value of MRI as the index test in the assessment of paediatric appendicitis and therefore this review provides a significant contribution to the evidence base.

## Method

A search of Medline, Cinahl and PubMed central databases and Google Scholar was undertaken supplemented by hand searching of key imaging journals (e.g. British Journal of Radiology;

Radiography), review of reference lists, author searching and review of the NICE (National Institute for Health & Care Excellence) evidence base for existing guidelines. Citations were identified using the following key search terms (and their alternatives): Magnetic Resonance Imaging (MRI; MR; Nuclear Magnetic Resonance (NMR)); Appendicitis (vermiform appendix, epiphylitis). The search was limited to primary research studies published from January 2005 to April 2015 to take account of the recent advances in MRI pulse sequences and the broader clinical application of the technology.

Following the identification of all potentially relevant research studies, the titles and abstracts were screened to determine whether they met the inclusion/exclusion criteria. These criteria were derived from the primary research question “is MRI a viable alternative to Ultrasound as the primary imaging modality in the diagnosis of paediatric appendicitis” and are listed in Table 1. Decision making around inclusion was based on the “rule out” principle with papers only being rejected where the reviewer was certain of their lack of relevance. At each stage, if uncertainty existed over whether a paper should be included in the review, the paper was retained. The full text of all retained articles was examined to make the final decision on inclusion/exclusion.

All retained full text papers were independently assessed for quality using the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2)<sup>23</sup> by at least 2 authors and data were extracted directly into a Microsoft Excel<sup>24</sup> spread sheet using a purposefully pre-designed extraction framework to promote consistency. Any inconsistencies in opinion re inclusion or paper quality were resolved through discussion and consensus agreement. Paper quality was documented using an adaptation of the QUADAS-2 assessment checklist summary criteria<sup>24</sup> (Table 2). A summary value was awarded to each paper in Table 3 with ‘High’ representing a study with low risk of bias and low concerns regarding applicability of study findings, ‘Average’ representing a study with an unclear risk of bias and unclear concerns regarding applicability, and ‘Low’ representing a study with a high risk of bias and high concerns regarding applicability. Only papers considered to be of high or average quality were retained in the final evaluation (Table 3).

Data analysis was by descriptive synthesis and comparison of extracted data. Meta-analysis or pooling of extracted data was not appropriate due to the diversity of study designs, variations in clinical characteristics and technical parameters, and differences in how diagnostic accuracy was determined.

**Table 1**  
Inclusion/Exclusion criteria.

Question facet	Inclusion	Exclusion
Population	Children 0–19 years with suspected appendicitis.	Adults studies involving children but where child data could not be independently evaluated.
Index test	MR	Studies not involving MRI or where MRI data cannot be independently evaluated.
Comparison test	Ultrasound	Other imaging modalities
Outcome measures	Sensitivity and specificity Diagnostic accuracy Examination time	
Study design	Diagnostic test studies	Studies without comparison between ultrasound and MRI. Qualitative studies
Reference standard	Surgical confirmation Histopathology Clinical follow-up of symptoms	

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