

# Evaluating the Value of Different Sonographic Findings in Diagnosis of Acute Appendicitis in Children

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## Abstract

**Introduction:** Appendicitis is one of the most common paediatric surgical emergencies occurring in about 7% of healthy children. To make a definitive diagnosis preferably avoiding unnecessary X-ray radiation exposure, ultrasound is the ideal modality. The aim of this study is to evaluate the diagnostic value of sonographic findings in children with acute appendicitis and comparing them with surgical findings to demonstrate the safety, simplicity and accuracy of this procedure in emergency departments as the first diagnostic procedure. **Materials and Methods:** One hundred and eight children aged 1–15 years suspected of acute appendicitis in our tertiary hospital emergency department enrolled the study. Patients presenting as acute abdomen suspected as having acute appendicitis underwent abdominal ultrasonography (US) at first. Sonographic findings were compared to surgical and pathologic results, and sensitivity and specificity of each sonographic parameter in paediatric appendicitis were evaluated. **Results:** The analysis of sonographic results showed that 67.6% of patients had acute appendicitis, 13.9% had perforated appendicitis and 18.5% had normal appendix. On the other hand, there were acute appendicitis in 63.9% of patients, perforated appendicitis in 12% and normal appendix in 8.3% in surgical reports. Sensitivity of uncompressible appendicitis, appendicitis, maximal outer diameter (MOD) above 6 mm, maximal mural thickness (MMT) above 3 mm, round appendix was 98.68%, 28.04%, 94.74%, 61.84% and 68.42%, respectively. Specificity of incompressible appendicitis, appendicitis, MOD above 6 mm, MMT above 3 mm, round appendix was 64.71%, 96.15%, 64.71%, 82.35% and 94.12%, respectively. Overall sensitivity and specificity of US in appendicitis were 97.56% and 69.23%, respectively. **Conclusion:** According to the findings of this study, sensitivity of US in diagnosing appendicitis is higher than other studies, but its specificity was lower. Ultrasonographic accuracy and efficacy to diagnose acute appendicitis in children are high enough to allow clinicians to do it as an imaging modality of first choice, and also, in problematic cases to assist correct clinical diagnosis avoiding unnecessary X-ray exposure, decreasing negative appendectomies, decreasing perforation rate and lowering the cost of patients. Furthermore, negative US do not justify immediate computed tomography because clinical re-evaluation and a second US can help greatly the clinicians in the correct diagnosis.

**Keywords:** Acute abdomen, appendicitis, child, imaging, surgery, ultrasonography

## INTRODUCTION

Appendicitis is the most common indication of surgery of children presenting with acute abdomen. Perforation of appendix can lead to morbidity and mortality of patient and surgeon's goal is to diagnose appendicitis before its perforation.<sup>[1]</sup> However, early and certain diagnosis is not possible in some children because younger children cannot explain their symptoms clearly and physical examination results are not very specific. Furthermore, children are more susceptible to perforation and indeed the risk of perforation has a reverse relationship

with age. Overall, the clinical diagnosis of acute appendicitis remains difficult in some cases, both in the children and adults, especially because of atypical presentation in most of these cases. Furthermore, symptoms are frequently non-specific and may overlap with other acute abdominal problems.<sup>[2]</sup>

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There are several findings favouring to diagnose acute appendicitis, such as leucocytosis, elevated C-reactive protein, abdominal X-ray and Alvarado scoring system; however, all of these tests are non-specific and cannot be used to insure accurate diagnosis. Graded compression sonography is a fast, safe, non-invasive inexpensive and available technique to diagnose acute appendicitis with sensitivities ranging from 75% to 89%.<sup>[3]</sup> Despite all improvements in clinical and laboratory findings and various scoring systems in clinical decision-making, the fundamental decision whether to operate or not remains on the sum of clinical and paramedical grounds.<sup>[4,5]</sup> There are several studies in different countries regarding accuracy of ultrasonography to diagnose acute appendicitis.<sup>[6-8]</sup> All of these studies indicate that sonography is a high-valued technique in the diagnosis of acute appendicitis. In 2007, a systematic review including 9121 patients of 25 studies reported 83.7% sensitivity, 95.9% specificity, 92.9% accuracy, 89.8% positive predictive value (PPV) and an 93.2% negative predictive value (NPV) for ultrasonographic study in the diagnosis of acute appendicitis studies.<sup>[9]</sup>

Most of the previous studies reported the feasibility, availability and overall accuracy of sonographic study in acute appendicitis.<sup>[10]</sup> There are convincing results on the high accuracy of computed tomography (CT) scanning in the diagnosis of acute appendicitis in children. A meta-analysis included 9330 patients published in 28 studies reported a significant difference in the NAR, from 16.7% using clinical evaluation without imaging compared to 8.7% with the use of CT scanning.<sup>[11]</sup> However, CT still retains its advantageous of less operator dependency, easier visualisation of the appendix in retrocaecal or aberrant locations and a better overview in cases of complication and or perforated appendicitis. Overall sensitivity in one meta-analysis of paediatric patients showed that CT was 6% more sensitive than ultrasound.<sup>[12]</sup> In adult and especially in old patients, where the sensitivity of US might be limited and important differential diagnoses have to be considered, CT might be used as the first-line imaging study of patients.<sup>[13]</sup> Some of the previous studies classified the sonographically non-visualised appendix as normal appendix.<sup>[14]</sup> It is quite obvious that body mass, thickness of the body wall and local pain might be the factors responsible to obscure or hide the appendix. Furthermore, visualisation of the appendix is sometimes very difficult by compression US.<sup>[15,16]</sup> In another retrospective study in children, the appendix could not be visualised in 241 cases (38%). The authors recommend second US study in some cases like those with large amounts of free intrabdominal fluid, phlegmon and pericaecal inflammation of fat tissues. Such studies showed that second US had a higher specificity (98%–100%) to diagnose acute appendicitis.<sup>[17,18]</sup> c gained its relevance as a problem-solving technique, especially when US is totally inconclusive and mainly where radiation protection is of special importance such as pregnant women or children. When the appendix visualizes clearly on US and magnetic resonance imaging (MRI), sensitivity and specificity of MRI are 100%, but, in US, they are 50% and 100%, respectively. Clearly, such study is the good example of a study

that is limited by small study population and low prevalence of the disease.<sup>[19]</sup> Paying attention to the importance of acute appendicitis in paediatric population we decided to perform this study to evaluate diagnostic value of sonographic findings in this age group.

## MATERIALS AND METHODS

In this cross-sectional study, 108 children aged 1–15 years suspected as having acute appendicitis visited emergency room were evaluated. All children with clinical signs of acute appendicitis (pre-umbilical pain shifted to right lower quadrant (RLQ) accompanied by tenderness of McBurney's point and leukocytosis), and other patients in whom appendicitis was not rolled out completely on clinical ground and laboratory findings were enrolled in the study. The informed consent for entering the study was got from the parents of the patient. Two expert radiologists with at least 5 years of work experience in the field of paediatric radiology and sonography performed the sonographic studies. Canadian-made devices QSonix made by Ultrasonix factory and ultrasound machine G50 made in Germany by Siemens factory were used. Sonography was done using Linear and convex probe with the frequency of 3.5–5 and 7–10 MHz with gradual compression techniques (Graded compression). The right side of the abdomen was examined at various levels, particularly in the area of maximum tenderness. When the appendix where seen, characteristic details of appendix and its surrounding areas were recorded. If the appendix was normal or could not be seen, the abdomen and pelvic area were fully examined to find any other pathologies. Sonographic indices to diagnose acute appendicitis include: Non-compressibility, maximal outer diameter (MOD) above 6 mm, maximal mural thickness (MMT) more than 3 mm, presence of appendicolith, increased echogenicity of tissues around the appendix, absence of sub-mucosal echogenic layer and presence of loculated fluid around the appendix. In most cases, the last two items were the signs of perforation. All patients with confirmed appendicitis on sonography and those highly suspected based on the clinical and laboratory findings underwent surgery. In cases in whom US did not confirmed appendicitis, patients were either operated or followed up for the next 3 days according to surgeon's decision. Other non-surgical problems founded include mesenteric adenitis, intussusception, gastroenteritis, haemorrhagic ovarian cyst in female adolescent, abdominal migraine and urinary tract infection. In some of these cases with doubtful findings, other procedures such as colour Doppler sonography is helpful and CT scanning are very helpful. Sonographic findings were compared with surgical and clinical findings of patients and the results were analyzed by SPSS version 22. Central indices (mean and medium) and standard deviation were reported. The Chi-square test used to compare the findings of sonographic reports and surgical and non-surgical results. Sensitivity and specificity of each sonographic parameter were evaluated separately.

**Table 1: Sensitivity and specificity of sonographic findings and appendicitis**

Sonographic finding	Sensitivity	Specificity	P
Uncompressible appendicitis	98.68	64.71	<0.001
Appendicitis	28.04	96.15	<0.006
MOD above 6 mm	94.74	64.71	<0.001
MMT above 3 mm	61.84	82.35	<0.001
Round appendix in transverse view	68.42	94.12	<0.001
Appendicitis	97.56	69.23	<0.001

MOD: Maximal outer diameter, MMT: Maximal mural thickness

**Table 2: Comparing sonographic reports with surgical findings of patients**

Reported diagnosis	Sonographic (%)	Surgical (%)
Acute appendicitis	67.7	63.9
Perforated appendicitis	13.9	12
Normal appendix	18.5	8.3

**Table 3: Comparing sonographic diagnosis and surgical or non-surgical findings**

	Sonographic diagnosis, n (%)	Surgical and non-surgical findings, n (%)
Acute appendicitis	73 (67.6)	69 (63.9)
Perforated appendix	15 (13.9)	13 (12)
Intact appendix	20 (18.8)	9 (8.3)
Other diagnoses	-	4 (3.7)
Non-operated patients	-	13 (12.1)
Total	108 (100)	108 (100)

## RESULTS

In this study, 108 children who were suspicious to appendicitis were evaluated. Among them, 37 cases (34.3%) were female and 71 cases (65.7%) were male. The mean age of patients was  $8.02 \pm 2.98$  years. Upon sonographic evaluation in 93 cases (86.1%), the appendix was seen. Among them, in 81 cases (87.1%), the appendix was not compressible, and in 12 cases, (12.9%) it was compressible. Appendix lumen was empty in 12 cases and contained gas in 13 cases, faeces in 42 cases and fluid in 26 cases.

Patients were divided into two groups based on MMT: In 50 cases (53.8%), it was equal or above 3 mm and in 43 cases (46.2%) it was <3 mm. On the basis of MOD patients divided into two groups: In 78 cases (73.9%) it was equal or more than 6 mm, and in 15 cases (16.1%), it was <6 mm. Appendicitis were present in 84 cases (77.8%). In the evaluation of echogenicity of sub mucosal layers, diffuse loss was seen in 8 cases (8.6%), focal loss was seen in 26 cases (28%) and it was intact in 59 cases (63.4%). Evaluation of appendix site revealed abdominal appendix in 57 cases (61.3%), retro-caecal appendix in 22 cases (23.7%) and pelvic appendix in 14 cases (15.1%). Appendix shape

in transvers view was ovoid in 40 cases (43%) and round in 53 cases (57%).

In the evaluation of peri-appendix area, there were increased echogenicity in 48 cases (44.4%), loculated fluid around the appendix in 16 cases (14.8%), pre-umbilical and RLQ lymph node larger than 4 mm in 38 cases (35.2%) and mass around the appendix in 8 cases (7.4%). In 13 cases, surgery did not performed and they were observed for 72 according the surgeon's decision. Their signs and symptoms were resolved either without intervention or with medical support.

Significant association was found between the diagnosis of acute appendicitis and non-compressibility of appendix ( $P < 0.001$ ), MMT equal or above 3 mm ( $P = 0.001$ ), MOD equal or above 6 mm ( $P < 0.001$ ), presence of appendicolith ( $P = 0.006$ ) and round-shaped appendix in transverse view ( $P < 0.001$ ); however, no significant association was found between the diagnosis of appendicitis and echogenicity around the appendix ( $P = 0.176$ ), presence of loculated fluid around the appendix ( $P = 0.573$ ) and mass around the appendix ( $P = 0.296$ ). Overall, in this study, US had 97.56% sensitivity and 69.23% specificity in the diagnosis of acute appendicitis. Table 1 shows sensitivity and specificity of sonographic findings in appendicitis. Table 2 demonstrates comparing of the sonographic reports and surgical findings of operated patients. Table 3 compares the sonographic diagnosis and surgical or non-surgical findings.

## DISCUSSION

Acute appendicitis is one of the most common and challenging diagnoses in paediatric emergency room and it is a very challenging decision-making in some cases.<sup>[16]</sup> These patients would benefit from an assisted early diagnosis, which could decrease risk of appendix perforation and other complications. Graded compression sonography is valuable in the clinical diagnosis of acute appendicitis. However, recently reported low sensitivity (29%) in the detection of appendicitis in patients with perforation suggests a relative limitation of this technique. It is likely that focal peritonitis associated with perforation may lead to inadequate compression and extensive necrosis of the appendix renders it difficult to be visualize.<sup>[20]</sup> In a review article by Schwerk, accuracy of diagnosing appendicitis by US was more than clinical and using sonography reduced the number of negative laparotomies.<sup>[5]</sup>

A systematic review in 2007 including 25 studies reported a sensitivity of 83.7%, specificity of 95.9%, accuracy of 92.2%, PPV of 89.8% and NPV of 93.2% for US diagnosis of AA.<sup>[9]</sup> Khalid *et al.* performed a prospective study on ultrasonographic examination in 146 children presenting with acute abdominal pain at the emergency ward or paediatric outpatient department. It was noted that initial purely clinical diagnosis was correct in only 38.3% of the cases. Ultrasonography was diagnostic in 45% of cases, while it provided only supportive clues for the diagnosis in 12% of cases. Thus, the overall efficacy of ultrasonography in acute abdominal pain in children was around 57%. Therefore, the diagnostic value of US in workup

of children with acute abdomen changed the management plan in a significant number of patients.<sup>[14]</sup> Most of the literature has reported a high NPV of US up to 95%–98%.<sup>[21–23]</sup> In our study, non-compressibility was seen in 87.1% of patients who their appendix was visible in the sonogram and this finding had high sensitivity of 98.68% and specificity of 64.7% in diagnosis. Compared to previous reports, sensitivity of incompressibility was more in our study, while its specificity was less.

For example, in the study by Schwerk in Germany, sensitivity and specificity of ultra sonography were 89.7% and 98.2%, respectively. However, in that study, most patients had appendiceal abscess, which made the diagnosis easier and increased sensitivity of this method.<sup>[5]</sup> From 2008–2013, another study reported a significant increase in the use of ‘US at first’ among 3353 children in Washington (following national recommendations to use US in diagnosis of AA when possible). Over 40% of these children were also examined by CT scanning of whom, 35% of all CT examinations were performed after doing US study which were indeterminate.<sup>[24]</sup>

Je *et al.* evaluated MOD and MMT of appendix in children diagnosed with acute appendicitis to set a diagnostic cutoff for acute appendicitis. Optimal cutoffs for MOD and MMT in diagnosing children appendicitis were >0.75 cm (95.4% sensitivity and 93.4% specificity) and >0.22 cm (90.7% sensitive and 79.3% specific). Finally, MMT and MOT reported as reliable findings in the diagnosis of acute appendicitis in children.<sup>[24]</sup> In our study, MOD equal or above 6 mm was 95% sensitive and 65% specific, which has diagnostic value similar to incompressibility. MMT equal or above 3 mm had 62% sensitivity and 82% specificity and was more specific than conventional diagnostic parameters such as MOD and incompressibility. It seems that by more evaluation of accuracy of each sonographic parameter in the diagnosis of acute appendicitis in children, we can set more effective criterion and cutoffs to increase diagnostic accuracy of sonography in acute and complicated appendicitis helping earlier diagnosis of this condition.

In some cases when MRI examination or CT cannot be done (because of mandatory radiation protection like in children and pregnant patients), there might be need to do second US examination. A recent meta-analysis study demonstrated that an imaging protocol using US as the first-line imaging study followed by CT scanning offers significant cost savings over a CT-only protocol and avoids unnecessary radiation exposure.<sup>[13]</sup> In a Markov-based decision model of paediatric appendicitis, the most cost-effective method of imaging in children with suspected AA was starting with US and following each negative US examination with a CT examination.<sup>[25]</sup> However, the economic and radiation burden considerations have to be tailored to the specific health-care system and cannot be done at all clinical and geographic settings.

## CONCLUSION

This study shows that sensitivity of US in diagnosing appendicitis is very high. Several findings such as incompressibility, MOD above 6 mm have high sensitivity but they have low specificity. Other findings such as MMT above 3 mm, submucosal echogenicity, appendicolith and loculated fluid behind appendix, mass and round cross view of appendix also, have high specificity with low sensitivity. Overall, in this study, US had 97.56% sensitivity and 69.23% specificity in the diagnosis of acute appendicitis.

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## Conflicts of interest

There are no conflicts of interest.

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