Section: Miscellaneous

Original Research Article

CLINICAL AND SONOGRAPHIC PREDICTORS OF PEDIATRIC APPENDICITIS: A PROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background: Acute appendicitis is a frequent cause of abdominal pain requiring urgent surgical intervention in children. Timely and accurate diagnosis is essential to prevent complications such as perforation and peritonitis. Ultrasound has emerged as the preferred first line imaging modality due to its accessibility, absence of ionizing radiation, and ability to support clinical decision-making when combined with established scoring systems. This study was designed to evaluate the diagnostic performance of ultrasound in suspected pediatric appendicitis and correlate with clinical assessment and operative outcomes.

Materials and Methods: A total of 72 children aged 2-18 years presenting with clinical features suggestive of acute appendicitis. All patients underwent structured clinical evaluation with Alvarado scoring followed by graded-compression ultrasound performed by experienced radiologists. Sonographic parameters were recorded. Final diagnosis was confirmed by intraoperative findings and histopathology in surgically managed cases, and by clinical follow-up in conservatively treated patients. Diagnostic metrics were calculated using standard statistical methods, and ROC analysis assessed overall discriminatory ability.

Results: Ultrasound visualized the appendix in 88.9% of cases and was suggestive of appendicitis in 50 patients. Non-compressible appendix and diameter ≥6 mm were the most frequent indicators. Compared with final diagnosis, ultrasound demonstrated a sensitivity of 90%, specificity of 77.3%, positive predictive value of 90%, negative predictive value of 77.3%, and an overall diagnostic accuracy of 86.1%. ROC analysis yielded an area under the curve of 0.83, indicating good discriminatory performance.

Conclusion: Ultrasound provides high diagnostic accuracy in pediatric appendicitis and remains a reliable first-line imaging tool. When interpreted alongside clinical scoring systems, it enhances diagnostic confidence, reduces radiation exposure, and supports timely surgical decision-making.

Keywords: Pediatric appendicitis, Ultrasound, Acute abdomen, Alvarado score, Diagnostic accuracy, ROC curve.

INTRODUCTION

Acute appendicitis is one of the most common surgical emergencies in childhood and a major cause of acute abdominal pain worldwide. Although mortality is low with timely intervention, delayed or missed diagnosis can lead to perforation, peritonitis, sepsis, prolonged hospitalization, and increased healthcare costs. Clinical features in children are often non-specific, overlap with other intra-abdominal conditions, and may be subtle in younger age groups, making purely clinical diagnosis challenging and contributing to negative appendectomy rates.[1,2]

Imaging has therefore become an essential adjunct in the diagnostic pathway. Computed tomography (CT) offers high sensitivity and specificity but exposes children to ionizing radiation and is associated with

higher cost and limited availability in some settings.[3] Concerns regarding cumulative radiation risk have driven a global shift towards radiation-sparing strategies and an "ultrasound-first" approach for children with suspected appendicitis, as endorsed by professional bodies such as the American College of Radiology and pediatric surgical societies.[4]

Graded-compression ultrasonography is widely available, non-invasive, and free of radiation, and allows dynamic assessment of the right iliac fossa together with identification of alternative diagnoses.[5] Large multicentre cohorts and meta-analyses have reported ultrasound sensitivities ranging from approximately 72-95% and specificities of 90-97%, with performance improving when the appendix is clearly visualized and standardized scanning protocols are used.[6,7] Recent work, including studies from Indian and international centers, has further highlighted that pediatric appendiceal ultrasound can approach "gold-standard" diagnostic accuracy and substantially reduce negative appendectomy and CT utilization when integrated into structured care pathways.[8,9]

Despite this, ultrasound remains operator-dependent, and reported diagnostic performance varies between institutions, influenced by sonographer experience, equipment, patient body habitus, and use of adjunctive clinical scores.[10] There is a continuing need for centre-specific evaluation of ultrasound accuracy and its correlation with clinical findings and histopathology, particularly in resource-limited, high-volume pediatric settings.

The present study aims to assess the role of ultrasound in diagnosing suspected acute appendicitis in children, determine its sensitivity, specificity, predictive values and overall accuracy, and correlate sonographic findings with operative and histopathological outcomes. By generating local performance data and examining how ultrasound findings relate to clinical evaluation, this work seeks to support evidence-based, radiation-sparing diagnostic algorithms for pediatric appendicitis in our tertiary care environment.

MATERIALS AND METHODS

This hospital based prospective, observational study was conducted in the Department of Pediatrics in collaboration with the Department of Radiodiagnosis at Prathima Relief institute of medical sciences, Warangal from June 2024 to October 2025. The written informed consent was obtained from parents or legal guardians after obtaining institutional ethical committee approval. A total of 72 children aged 2-18 years, presenting to the pediatric emergency and outpatient department with clinical suspicion of acute appendicitis, were enrolled consecutively based on predefined inclusion and exclusion criteria.

Inclusion Criteria

Children aged 2-18 years presenting with acute right lower quadrant abdominal pain suspicious of appendicitis, clinically suspected cases of acute appendicitis based on history and physical examination and willing to provide informed consent.

Exclusion criteria

Children with history of abdominal surgeries, with known abdominal masses, hemodynamically unstable patients requiring immediate surgical intervention without imaging, inflammatory bowel disease, tuberculosis, pelvic inflammatory disease and with inadequate visualization of appendix on ultrasound despite multiple attempts.

All enrolled participants underwent detailed clinical history, physical examination focusing on tenderness at McBurney's point, guarding, rigidity, and rebound tenderness, necessary laboratory investigations such as complete blood count, neutrophil-lymphocyte ratio, and C-reactive protein. The Alvarado Score was calculated for each patient to stratify clinical likelihood.

Ultrasound examinations were conducted in the radiology department utilizing high-resolution scanners, overseen by radiologists possessing at least three years of experience in pediatric imaging. These professionals were blinded to laboratory results yet informed of clinical symptoms, thereby emulating authentic diagnostic practices in a clinical setting. The findings underwent scrutiny by a second radiologist for validation.

The precision of ultrasound diagnosis was validated by intraoperative observations and histopathological analysis in patients undergoing surgical management. Clinical monitoring should be conducted over a period of 7 to 10 days for patients who have been conservatively managed and have received negative ultrasound results. The resolution of symptoms without surgical intervention was classified as a true negative, whereas persistent or worsening symptoms necessitating surgery were deemed false negatives.

Data were meticulously documented utilizing a structured proforma that encompassed socio-demographic information, clinical characteristics, the Alvarado score, ultrasound findings, operative and histopathological confirmations, as well as treatment outcomes. The diagnostic precision of ultrasound in pediatric appendicitis is associated with clinical characteristics and is evaluated against intraoperative findings. The evaluation of diagnostic performance metrics, including sensitivity, specificity, positive Predictive Value (PPV), negative Predictive Value (NPV), and diagnostic accuracy, was conducted.

Statistical Analysis: The collected data was analysed using SPSS v.26.0. Categorical variables were represented in frequency and percentages, continuous variables represented in mean and standard deviation. Chi-square test was used for categorical variables. A $p<0.05$ was considered as statistically significant.

RESULTS

A total of 72 children clinically suspected of acute appendicitis were included.

The mean age was 10.4±3.6 years (range: 3-17 years). Most cases were observed in the 10-14 year age group (41.7%). There was a male predominance (62.5%) [Table 1].

Table 1: Age and gender wise distribution (n = 72).

Category	Total cases (n=72)	
	Frequency	Percentage
Age (years)		
2-5	9	12.5%
6-9	18	25%
10-14	30	41.7%
15-18	15	20.8%
Gender		
Male	45	62.5%
Female	27	37.5%

Table 2: Alvarado score distribution.

Alvarado Score	Frequency	Percentage
≤6 (low probability)	18	25%
7-8 (probable appendicitis)	32	44.4%
≥9 (high probability)	22	30.6%

Table 3: Ultrasound visualization and suggestive findings.

Ultrasound parameter	Frequency	Percentage
Appendix visualisation		
Visualised	64	88.9%
Not visualised	8	11.1%
Ultrasound suggestive findings		
Suggestive appendicitis	50	69.4%
Not suggestive of appendicitis	22	30.6%

Table 4: Operative and histopathological outcomes.

Surgical outcome	Frequency	Percentage
Cases operated	50	69.4%
True appendicitis (HPE-confirmed)	45	62.5%
Non-appendicitis (post-op findings)	5	6.9%
Cases treated conservatively	22	30.6%

Table 5: Diagnostic performance of ultrasound.

Diagnostic category	Number
True Positive (TP)	45
False Positive (FP)	5
True Negative (TN)	17
False Negative (FN)	5

Figure 1: Clinical symptoms reported by study participants.

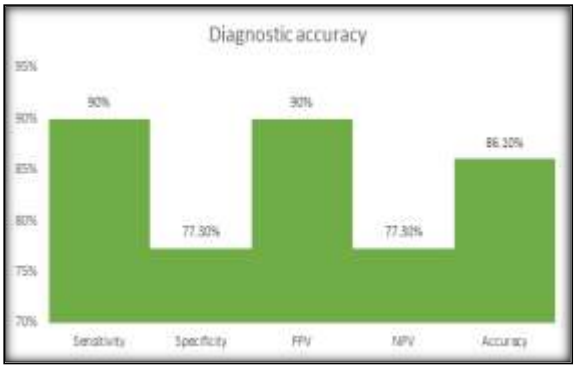

Figure 2: Outcome of diagnostic accuracy.

Abdominal pain was present in all cases (100%), followed by vomiting (72.2%), fever (63.9%), and anorexia (59.7%) [Figure 1].

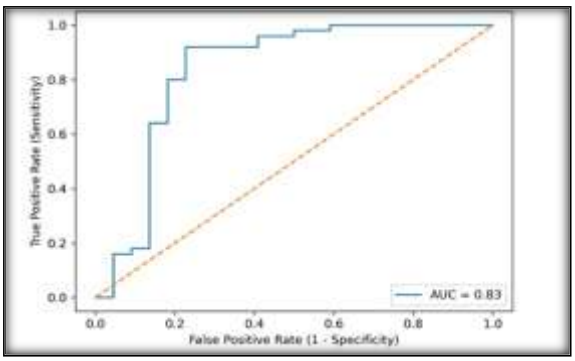

Figure 3: ROC Curve for ultrasound-based diagnosis of pediatric appendicitis.

The ROC curve demonstrated an AUC of 0.83, indicating good diagnostic discrimination of ultrasound in detecting pediatric appendicitis. The curve consistently maintained a high true positive rate across multiple thresholds, supporting ultrasound as a reliable first-line imaging modality [Figure 3].

DISCUSSION

Acute appendicitis remains one of the most frequent surgical emergencies in childhood, but its diagnosis is often challenging because symptoms are subtle, atypical or overlap with other causes of abdominal pain. Delayed or missed diagnosis increases the risk of perforation and postoperative morbidity, whereas over-diagnosis exposes children to unnecessary appendectomy.[1,11] Consequently, there has been a sustained shift towards imaging-guided decision making, with ultrasound preferred over CT to avoid ionising radiation in this vulnerable population.

In the current series, ultrasound performance lies towards the upper end of the range reported in the literature. A recent systematic review of emergency-department studies found that ultrasound for acute appendicitis showed pooled sensitivities of 75-90% and specificities of 86-95%, with substantial heterogeneity between centres.[6,12] Mittal MK et al., in a large multicentre cohort of children, reported an overall sensitivity of 72% and specificity of 97%, but when the appendix was clearly visualised, sensitivity increased to 98% and specificity to 92%.[6,13] The sensitivity (90%) and AUC (0.83) observed in our study are therefore consistent with high diagnostic performance, although the modest specificity suggests some over-calling of equivocal or borderline appearances.

In our cohort, the appendix was visualised in 88.9% of cases, which is higher than the visualisation rates of 60-80% reported previously and closer to the visualisation rates achieved in centres with established paediatric ultrasound pathways. Binkovitz LA et al. showed that improved protocols, experienced sonographers and structured reporting reduce the proportion of indeterminate scans and are associated with fewer CT examinations and negative appendectomies.[14] The high visualisation rate in our study likely contributed to the good sensitivity and accuracy.

The sonographic pattern in our patients mirrors classical descriptions. Non-compressibility was the most frequent sign (62.5%), followed by outer diameter ≥6 mm, peri-appendiceal fat stranding and appendicolith. These parameters have been consistently identified as the strongest imaging predictors of appendicitis and form the basis of several ultrasound-based scoring systems. Pop et al. incorporated appendiceal diameter, wall layering and peri-appendiceal changes into a scoring algorithm and showed that higher scores correlated strongly with histologically confirmed appendicitis.[15] Our findings reinforce the value of carefully assessing secondary signs such as echogenic fat and peri-appendiceal fluid, especially when the appendix is only partly seen.

An important strength of the present work is the integration of ultrasound with the Alvarado score. We observed a clear increase in ultrasound positivity with rising clinical probability, and all children with an Alvarado score ≥9 had sonographic features of appendicitis. This is in agreement with studies showing that combining ultrasound with clinical scores significantly improves diagnostic confidence. Blitman NM et al. demonstrated that children with a low Alvarado score and inconclusive focused appendicitis ultrasound were extremely unlikely to have appendicitis, whereas concordant high scores and positive ultrasound virtually eliminated false positives. Other authors have also advocated a staged algorithm in which children with low scores are observed or discharged, those with intermediate scores undergo ultrasound, and CT or MRI is reserved for persistently equivocal cases.[12,16] Our results support such clinical-imaging pathways and suggest that they are applicable in resource-limited settings.

The diagnostic performance seen in this study is comparable with series from both radiologist-performed and non-radiologist-performed ultrasound. Khan U et al. reported a sensitivity of 86% and accuracy of 92% for ultrasound in a cross-sectional validation study of 223 children, showing that routine use of ultrasound can markedly reduce negative appendectomy without increasing CT utilisation.[17] A recent meta-analysis of non-radiologist-performed paediatric appendicitis ultrasound found pooled sensitivity and specificity of 87% and 93%, respectively, supporting the dissemination of point-of-care ultrasound with appropriate training.[18] Our data, acquired in collaboration with radiology specialists, fall within these ranges and emphasise that operator expertise and standardised protocols are more important than the specific clinical background of the sonographer.

In limitations, this was a single center study with 72 children, which may restrict diagnostic accuracy and disease severity. In cases when ultrasound-negative patients did not undergo appendectomy, clinical follow-up was used instead of histology, which could introduce verification bias and underestimate false negatives. Previous diagnostic investigations and meta-analyses raised similar problems.[12] Third, ultrasound's operator dependency limits sensitivity, especially in early or perforated illness, due to experience, equipment, and patient habitus.[14] In future research, this centre could implement structured ultrasound reporting templates, incorporate quantitative parameters like appendiceal diameter cut-offs and peri-appendiceal fat scores, and prospectively validate combined ultrasound clinical prediction models like Pop and colleagues.[15,19] Inter-observer variability and generalisability across practice environments could be assessed through multicenter collaboration.

CONCLUSION

Ultrasound is a reliable and effective first-line imaging modality for diagnosing suspected acute appendicitis in children. In this study, it demonstrated

high sensitivity, good specificity, and strong overall accuracy, with meaningful correlation to clinical findings and histopathology. The ability to visualize the appendix in most cases and identify key sonographic features supports its utility in guiding timely management while avoiding radiation exposure associated with CT. When combined with clinical scoring systems such as the Alvarado score, diagnostic confidence is further strengthened. Overall, ultrasound enhances decision-making, reduces unnecessary surgeries, and remains the preferred initial investigation in pediatric appendicitis.

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