Original Article

The Role of Alvarado Scores and Abdominal Ultrasonography in Paediatric Acute Appendicitis Diagnosis: A Retrospective Study

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Abstract

Background: Acute appendicitis is a prevalent surgical emergency for which clinical assessment plays a pivotal role. However, this condition's early stages and atypical presentation pose challenges in diagnosis owing to subtle clinical features. Abdominal ultrasonography (US) is a commonly employed radiologic technique that aids in diagnosis; however, it is contingent on the operator's skill. This study aimed to evaluate the diagnostic reliability of the Alvarado score (AS) and abdominal US in paediatric cases of acute appendicitis. **Materials and Methods:** A retrospective study conducted between May 2021 and Sep 2022 included 387 paediatric patients who operated for acute appendicitis at Alnasar Hospital, Ibb, Yemen. All patients were evaluated preoperatively through AS, determined through clinical evaluation, followed by abdominal US. The sensitivity, specificity, accuracy, positive predictive value (PPV) and negative predictive value (NPV) of US and AS were investigated using histopathological results as a golden standard modality. In addition, univariate and multivariate analyses investigated factors associated with accurate acute appendicitis diagnosis using odds ratio (OR) and 95% confidence interval (CI). **Results:** The negative appendicectomy rate was 17.1%. The AS sensitivity, specificity, accuracy, PPV and NPV were 89.72%, 81.82%, 88.4%, 96.0% and 62.1%, respectively. The US sensitivity, specificity, accuracy, PPV and NPV were 86.92%, 36.36%, 78.3%, 86.9% and 36.4%, respectively. Predictive factors for accurate appendicitis diagnosis were definite diagnosis in US (OR: 2.94; 95% CI: 1.13–7.88, $P = 0.029$), probable diagnosis in US (OR: 13.32; 95% CI: 2.79–75.33, $P = 0.002$), advanced AS (OR: 2.75; 95% CI: 1.10–7.27, $P = 0.034$) and children aged between 10 and 17 years (OR: 9.16; 95% CI: 2.32–37.97, $P = 0.002$). **Conclusion:** Alvarado's score and abdominal US exhibited high sensitivity in diagnosing acute appendicitis. The substantial accuracy and efficacy of the AS and US support their utilization as primary investigative tools in resource-limited settings.

Keywords: Acute appendicitis, Alvarado score, children, diagnosis, ultrasonography

Introduction

Amongst the causes of acute abdomen, acute appendicitis is one of the most frequently encountered surgical emergencies in children, with an estimated risk of 7%–8%.[1] Appendicitis diagnosis in children is difficult, not just because there are so many other non-surgical illnesses that look like appendicitis, but also because of communication and examination challenges.[2] Delayed intervention causes significant complications such as perforation and abscess development, whereas rushing to surgery is linked with a high negative appendectomy rate of up to 15%–30%.[3] There are various diagnostic criteria for early and correct diagnosis of appendicitis, as well as decreasing negative appendectomy owing to particular abdominal pain. These criteria include scoring systems, inflammatory factors, radiologic studies or a combination of these approaches.[2-4] Abdominal ultrasonography (US) is proposed as a non-ionising method for detecting acute appendicitis. Still, its accuracy remains low, leading to misdiagnosis, unnecessary surgery in up to 34% of cases, complications and a 1.5% death risk, requiring further therapy.[5,6] According to a literature review, abdominal US has significantly varied diagnostic accuracy in diagnosing acute appendicitis (sensitivity ranges from 44% to 100%; specificity ranges from 47% to 99%).[7] This is due to a variety of factors, including a lack of operator expertise, higher intestinal gas content, obesity, anatomic variations

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and restrictions in investigating patients with previous laparotomies.[7]

Several scoring methods and models have been proposed to improve diagnosis accuracy in patients with acute appendicitis, including the Alvarado, Lintula, Fenyo–Lindberg and RIPASA scoring systems.[4] The Alvarado score (AS), which uses eight predictive factors, is the most widely used.[8] However, previous studies have reported conflicting results, with racial differences as potential factors.[9-11] Some studies have found high sensitivity and advocated its frequent use,[9,10] whereas others have reported opposite results.[11] In a recent meta-analysis of 26 studies involving 5985 children from 11 countries, the AS had a combined sensitivity of 76.0% and a combined specificity of 71.0% for diagnosing acute appendicitis in children. In contrast, the modified AS had a combined sensitivity of 87.0% and a combined specificity of 47.0%.[12] Delayed or missed diagnosis of acute appendicitis can result in poor patient care, increased complications and legal claims, whereas overdiagnosis can lead to inappropriate surgical intervention.[13] In addition, few reports have looked at the relevance of scoring systems in determining the best therapeutic approach for children's patients with acute appendicitis, particularly in resource-limited settings.[4,13] This study aimed to investigate the diagnostic accuracy of abdominal US and AS for paediatrics with acute appendicitis in a resource-limited setting. The findings from this study may enhance appendicitis screening accuracy and reduce surgery costs by eliminating unnecessary appendectomies.

Materials and Methods

Study design

A retrospective cross-sectional study was conducted at Al Nasar Hospital, Ibb, Yemen, between May 2021 and September 2022, including children (aged <17 years) admitted with acute abdominal pain, diagnosed with acute appendicitis based on clinical suspicion and underwent appendectomy. AS was determined through clinical evaluation followed by abdominal US. Ethical approval for the study was obtained from the ethics committee of IBB University, and the study was conducted following the Declaration of Helsinki. After thoroughly explaining the research purpose, all the children's legal guardians consented to and signed an informed consent form for the gathering of data from their medical records, as well as the publishing of their medical information and photographs, at the time of registration.

Inclusion criteria

The study included paediatric patients under 17 years old with abdominal pain, including pain in the right iliac fossa, lower abdominal pain or other clinical symptoms suspected of acute appendicitis and admitted to the emergency department.

Exclusion criteria

Patients who were not evaluated with ASs, patients with previous intra-abdominal surgery, patients suffering from generalised peritonitis, or those who were recently treated for urinary tract infections were excluded from the study.

Data gathering

Patient information, including age, gender, previous abdominal pain attack, time to hospital presentation, C-reactive protein (CRP), AS, abdominal US report and final pathology report, was gathered from the medical records. AS was determined by clinical evaluation, as described in Table 1. Our criteria for abdominal US were the exact phrase "in favour of appendicitis (Positive US and probable US) or negative for appendicitis (Negative US)" written in the report. The criteria for AS were seven and above (highly suggestive of appendicitis), between 6 and 5 (suspected appendicitis), and four or below (Negative for appendicitis) for the diagnosis of acute appendicitis. Based on clinical examination, AS scores and US findings, we proceeded with surgical exploration. Data were collected through independent chart reviews. The collected data were thoroughly assessed for accuracy, completeness and consistency. In cases where contradictory or missing information was identified, the charts were reviewed and re-evaluated to ensure data quality. A negative appendectomy was defined as a normal appearance of the appendix and few or no acute inflammatory cells in the histopathological report.

Study outcome

The primary outcome was to investigate the diagnostic accuracy of abdominal US and AS in diagnosing paediatric acute appendicitis. The AS and abdominal US results were validated based on the pathology report of the removed appendix [Figure 1]. The secondary outcome was factors associated with accurate appendicitis diagnosis.

Statistical analysis

Continuous variables were reported using mean and standard deviation; categorical variables were reported as absolute numbers or percentages and compared using Chi-square or Fisher's exact tests. The sensitivity, specificity, accuracy, accuracy, positive predictive value (PPV) and negative predictive value (NPV) of US and AS in determining acute appendicitis were analysed using receiver operating characteristic (ROC) curves. Factors associated with accurate appendicectomy diagnosis were investigated in univariate and multivariate analysis using odds ratio (OR) and 95% confidence interval (CI). Statistical significance was set at $P < 0.05$. SPSS version 22 (IBM SPSS, version 22, Armonk, IBM Corp, Armonk, NY, USA) was used for data analysis.

Results

A total of 387 paediatric patients underwent appendectomy, and the results were confirmed by histopathological analysis. The mean age was 10.3 ± 4.0 years (range: 2–17 years); of them, 33 (8.5%) were aged between 2 and 5 years,

156 (40.3%) were aged between 5.1 and 10 years and 198 (51.2%) were aged between 10.1 and 17 years. Most cases were male children (n = 222, 57.4%). The mean time to presentation was 29.9 ± 17.7 h (range: 9.0–101.0 h). Previous attacks were reported in 69 (17.8%) patients. The mean AS was 7.0 ± 1.8, and an AS ≥7 was the common subtype (63.6%). US findings were unremarkable, with probable acute appendicitis and definite acute appendicitis in 66 (17.1%), 279 (72.1%) and 42 (10.9%), respectively. The histopathology report showed a normal appendix in 66 (17.1%) of cases (negative appendectomy rate), whereas 321 (82.9%) confirmed acute appendicitis pathology (positive appendectomy rate) [Table 2].

The AS sensitivity, specificity, accuracy, PPV and NPV were 89.72%, 81.82%, 88.4%, 96.0% and 62.1%, respectively. The ROC curve for AS showed a significant area under the curve (AUC) values (0.904; 95% CI, 0.840–0.949) for acute appendicitis diagnosis and was statistically significant (P < 0.0001) [Figure 2]. The US sensitivity, specificity, accuracy, PPV and NPV were 86.92%, 36.36%, 78.3%, 86.9% and 36.4%, respectively. The ROC curve for abdominal US showed a good AUC value (0.613; 95% CI: 0.523–0.697) for acute appendicitis diagnosis but was not statistically significant (P = 0.070) [Figure 2].

Factors associated with accurate appendicitis diagnosis

In the univariate analysis, US appearance (probable or definite acute appendicitis), high AS, CRP >6 mg/dl and longer time to presentation were significantly associated with acute appendicitis presentation (all P < 0.05) [Table 3]. In multivariate analysis, predictive factors for accurate appendicitis diagnosis were definite acute appendicitis diagnosis in US (OR: 2.94; 95% CI: 1.13–7.88, P = 0.029), probable acute appendicitis diagnosis in US (OR: 13.32; 95% CI: 2.79–75.33, P = 0.002), advanced ASs (OR: 2.75; 95% CI: 1.10–7.27, P = 0.034) and

Table 1: Alvarado score

Variables	Clinical features	Score
Symptoms	Migratory RIF pain	1
	Anorexia	1
	Nausea and vomiting	1
Signs	Tenderness of right iliac fossa	2
	Rebound tenderness	1
	Elevated temperature	1
Laboratory	Leucocytosis	2
	Shift to left	1
Total score	-	10

RIF: Right iliac fossa

Table 2: Demographic and diagnostic features of the participants (n=387)

Variables	n (%)
Age (year), mean±SD	10.3±4.0
Age group (years)	
Between 2 and 5	33 (8.5)
Between 5.1 and 10	156 (40.3)
Between 10.1 and 17	198 (51.2)
Gender	
Female	165 (42.6)
Male	222 (57.4)
History of previous abdominal pain	69 (17.8)
Time to presentation (h), mean±SD	29.9±17.6
AS variables	
Elevated temperature (>37°C)	324 (83.7)
Migratory RIF pain	261 (67.4)
Anorexia	243 (62.8)
Tenderness RIF	291 (75.2)
Nausea and vomiting	285 (73.6)
Rebound tenderness	246 (63.6)
Leucocytosis (>10,000/mL)	282 (72.9)
Shift to the left (polymorphonuclear neutrophilia >75%)	195 (50.4)
Total AS, mean±SD	7.0±1.8 (range: 3.0–10.0)
AS group	
Appendicitis unlikely	87 (22.5)
Suspected appendicitis	54 (14.0)
Appendicitis most likely	246 (63.6)
Ultrasound appearance	
Normal (unremarkable)	66 (17.1)
Definite acute appendicitis	279 (72.1)
Probable acute appendicitis	42 (10.9)
C-reactive protein (mg/dL)	
≤6	228 (58.9)
>6	159 (41.1)
Final pathology report	
Normal appendix	66 (17.1)
Appendicitis	321 (82.9)

SD: Standard deviation, RIF: Right iliac fossa, AS: Alvarado score



Figure 1: (a) Ultrasonographic views show the diameter of the appendix, (b) Ultrasonographic views of showing acute appendicitis, (c) Intraoperative views of removed inflamed appendix (perforated appendicitis)

Table 3: Univariate and multivariate analysis for predictive factors for accurate appendicitis diagnosis

Variables	Subgroups	Negative appendectomy (*n*=66; 17.1%)	Positive appendectomy (*n*=321; 82.9%)	Univariate		Multivariate	
				OR (95% CI)	*P*	OR (95% CI)	*P*
Age group	Between 2 and 5 years	9 (27.3)	24 (72.7)	Reference group		Reference group	
	Between 5.1 and 10 years	36 (23.1)	120 (76.9)	1.25 (0.51–2.86)	**0.608**	1.57 (0.43–5.46)	0.486
	Between 10.1 and 17 years	21 (10.6)	177 (89.4)	3.16 (1.25–7.56)	**0.011**	9.16 (2.32–37.97)	**0.002**
Time to presentation (h)	Mean±SD	20.5±7.4	31.8±18.5	1.07 (1.04–1.10)	**<0.001**	1.03 (0.99–1.08)	0.204
Elevated temperature (>37°C)	No	21 (33.3)	42 (66.7)	Reference group		Reference group	0.139
	Yes	45 (13.9)	279 (86.1)	3.10 (1.66–5.68)	**<0.001**	2.51 (0.75–8.72)	
Anorexia	No	33 (22.9)	111 (77.1)	Reference group		Reference group	0.438
	Yes	33 (13.6)	210 (86.4)	1.89 (1.11–3.24)	**0.019**	0.62 (0.18–2.05)	
Tenderness RIF	No	33 (34.4)	63 (65.6)	Reference group		Reference group	0.958
	Yes	33 (11.3)	258 (88.7)	4.10 (2.35–7.16)	**<0.001**	1.05 (0.18–6.16)	
Nausea and vomiting	No	36 (35.3)	66 (64.7)	Reference group		Reference group	0.783
	Yes	30 (10.5)	255 (89.5)	4.64 (2.67–8.13)	**<0.001**	1.21 (0.31–4.71)	
Rebound tenderness	No	39 (27.7)	102 (72.3)	Reference group		Reference group	0.225
	Yes	27 (11.0)	219 (89.0)	3.10 (1.81–5.39)	**<0.001**	2.16 (0.64–7.78)	
Leukocytosis (>10,000/mL)	No	36 (34.3)	69 (65.7)	Reference group		Reference group	0.279
	Yes	30 (10.6)	252 (89.4)	4.38 (2.53–7.66)	**<0.001**	2.55 (0.48–14.48)	
Shift to left (polymorphonuclear neutrophilia >75%)	No	51 (26.6)	141 (73.4)	Reference group		Reference group	0.283
	Yes	15 (7.7)	180 (92.3)	4.34 (2.40–8.29)	**<0.001**	0.44 (0.10–1.93)	
AS	Mean±SD	4.9±1.0	7.4±1.6	3.20 (2.49–4.28)	<0.001	2.75 (1.10–7.27)	**0.034**
Ultrasound appearance	Normal (unremarkable)	24 (36.4)	42 (63.6)	Reference group		Reference group	
	Definite acute appendicitis	36 (12.9)	243 (87.1)	3.86 (2.08–7.11)	**<0.001**	2.94 (1.13–7.88)	**0.029**
	Probable acute appendicitis	6 (14.3)	36 (85.7)	3.43 (1.33–10.09)	**0.016**	13.32 (2.79–75.33)	**0.002**
C-reactive protein (mg/dL)	≤6	48 (21.1)	180 (78.9)	Reference group		Reference group	0.114
	>6	18 (11.3)	141 (88.7)	2.09 (1.18–3.83)	**0.014**	2.53 (0.82–8.39)	

Boldface indicates a statistically significant result ($P<0.05$). RIF: Right iliac fossa, OR: Odds ratio, CI: Confidence interval, SD: Standard deviation, AS: Alvarado score

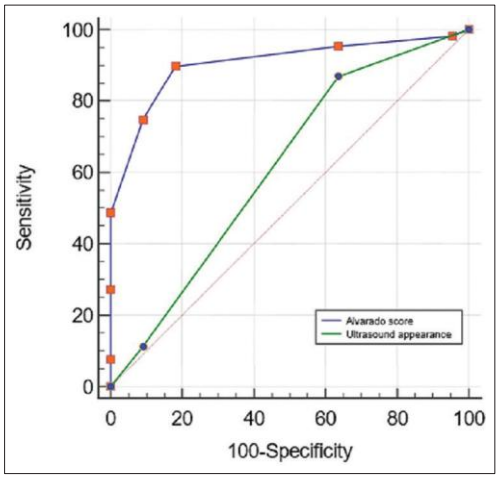


Figure 2: Receiver-operating characteristic (ROC) curve showing the diagnostic accuracy of the Alvarado Score (AS) and ultrasound (US). Sensitivity, Specificity and area under the curve (AUC) of AS and US. The AUC for the ROC curve of AS was 0.904 with a 95% confidence interval (CI), 0.840–0.949 and was statistically significant ($P < 0.0001$) and abdominal US. The AUC for the ROC curve of abdominal US was 0.613 with a 95% CI, 0.523–0.697 for acute appendicitis diagnosis but was not statistically significant ($P = 0.070$)

children aged between 10 and 17 years (OR: 9.16; 95% CI: 2.32–37.97, $P = 0.002$).

Discussion

In this study, we investigated the role of abdominal US and ASs in paediatric acute appendicitis diagnosis. Our result showed that Alvarado's score and abdominal US exhibited high sensitivity when diagnosing acute appendicitis. The substantial accuracy and efficacy of the AS and the abdominal US support their utilisation as primary investigative tools in resource-limited settings. Acute appendicitis is a prevalent cause of abdominal discomfort and a primary cause of emergency surgical intervention worldwide.[1,14] Most diagnoses rely on clinical records and examinations, particularly the progression of mid-abdominal discomfort to the right iliac fossa.[15] However, appendicitis may occasionally manifest with atypical symptoms, leading to delayed or inaccurate diagnoses.[15] Studies indicate that unnecessary laparotomy for acute appendicitis occurs at a rate of approximately 20%–25%.[16,17] The decision to pursue surgical intervention in cases of suspected appendicitis represents a critical management juncture. Thus, any diagnostic method enhancing accuracy in this regard would be advantageous.

The objective of radiologic imaging in acute appendicitis diagnosis is to improve diagnostic efficacy while minimising patient costs and risks.[18] Research suggests that graded compression US is particularly valuable in cases where clinical

symptoms make appendicitis detection challenging, effectively reducing the rate of negative appendectomies.[18,19] Yu *et al*.'s 2005 meta-analysis found a negative appendectomy rate of 10.7% in suspected appendicitis patients who underwent US, whereas the rate ranged between 10% and 20% in non-US patients.[20]

In this study, we evaluated the role of AS and US in paediatric patients with suspected acute appendicitis compared to post-operative histopathological findings. This study showed that the abdominal US had a high sensitivity of 86.92% for detecting acute appendicitis; however, US had a low specificity of 36.36%. Its PPV, NPV and accuracy were 78.3%, 86.9% and 36.4%. Several studies have been conducted on the use of abdominal US to confirm or exclude acute appendicitis in suspected individuals. For example, in a study by Hosseini *et al*., the sensitivity, specificity, PPV and NPV of the US were 58%, 68%, 77% and 46%, respectively.[15] In the Mán *et al*. study, the sensitivity and specificity were 82.6% and 87%.[21] In another study by Chen *et al*., patients in the emergency department were divided into two groups: Group I, diagnosed using US and Group II, diagnosed based on the surgeon's clinical impression. The diagnosis of acute appendicitis was confirmed through pathological reports, with Group I having higher sensitivity and specificity. The sensitivity and specificity were 96.4% and 67.6%, respectively. The PPV, NPV and accuracy of the US were 89.8%, 86.2% and 89.1%, respectively.[22] The quality of US results depends heavily on the radiologist's expertise and precision and the appendix's varied position, which hinders its detection by US. Consequently, one of its drawbacks is its reliance on individuals who produce differences in the outcomes of numerous investigations.[23-27] The main reason for the low specificity in this study was that all US procedures were performed by a general radiologist (not a paediatric sonologist) in an educational centre. Similar to our results, a review study by Pinto *et al*. found that US has varying diagnostic accuracies for acute appendicitis, with sensitivity ranging from 44% to 100% and specificity ranging from 47% to 99%. The authors attributed this to operator skills, increased gas volume, obesity and previous laparotomies.[7] Other studies that reported low US specificity were Chen *et al*., with a specificity of 67.6%; Pedram *et al*., with a specificity of 68% and Afridi *et al*., with a specificity of 70.59%.[22,27,28] In Ashjaei *et al*., the overall sensitivity and specificity of US for appendicitis diagnosis were 97.56% and 69.23%, respectively.[29]

The AS system is based on symptoms, physical examination and laboratory test results. It is a susceptible method for identifying patients with probable acute appendicitis.[9] In this study, the AS sensitivity, specificity, accuracy, PPV and NPV for detecting acute appendicitis were 89.72%, 81.82%, 88.4%, 96.0% and 62.1%, respectively. Our results match those of Kanumba *et al*., who observed the AS sensitivity, specificity, PPV, NPV and accuracy to be 94.1%, 90.4%, 95.2% and 88.4%.[30] Similar results have been reported by Bouali *et al*.[9] In this study, with AS scores of more than seven, AS sensitivity, specificity, PPV and NPV were 94.9%, 72.7%, 98.4% and 44.4%, respectively.[9] In the Memon *et al*. study, the AS demonstrated high sensitivity and specificity of 93.5% and 80.6%, with PPV and NPV of 92.3% and 83.3%, respectively, and an accuracy of 89.8%.[31]

In this study, predictive factors for accurate appendicitis diagnosis were definite acute appendicitis diagnosis in US (OR: 2.94; 95% CI: 1.13–7.88, $P = 0.029$), probable acute appendicitis diagnosis in US (OR: 13.32; 95% CI: 2.79–75.33, $P = 0.002$), high ASs (OR: 2.75; 95% CI: 1.10–7.27, $P = 0.034$) and children aged between 10 and 17 years (OR: 9.16; 95% CI: 2.32–37.97, $P = 0.002$). The result was similar to previous reports.[32-35] According to Zouari *et al*., an Alvarado's score of ≥6 and higher peri-appendiceal fat echogenicity were associated with acute appendicitis. These two criteria combined to offer a 100% positive prediction value. Furthermore, a WBC count of $\leq 10 \times 10^9$/L and/or a C- CRP of ≤6 mg/L makes the diagnosis of appendicitis unlikely.[32]

Study limitations and strengths

This study has significant limitations. The primary drawbacks were its retrospective nature and small sample size. Consequently, excluding all potential confounding factors and biases from the study was impossible. Furthermore, because the current investigation was conducted at a single centre, the generalisability of the results to all clinical circumstances was limited. Additional limitations of this study include the lack of evaluation of predictors of complex appendicitis, post-operative complications and other variables that may impact the findings. Nonetheless, by providing information on potential predictive indicators and diagnostic accuracy of Alvarado criteria and US for appendicitis diagnosis in Yemeni children, our findings provide a major contribution to the literature on appendicitis diagnosis in resource-limited settings. We recommend conducting a prospective multicentre investigation with a larger sample size to validate our results.

Conclusion

Alvarado's score and abdominal US exhibited high sensitivity in diagnosing acute appendicitis. The substantial accuracy and efficacy of the AS and US support their utilisation as primary investigative tools in resource-limited settings. This approach can help avoid unnecessary appendectomies, reduce dependency on computed tomography scans and minimise the financial burden.

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Conflicts of interest

There are no conflicts of interest.

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