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ORIGINAL RESEARCH

Evaluating the Diagnostic Accuracy of the Alvarado Score and Abdominal Ultrasound for Acute Appendicitis: A Retrospective Single-Center Study

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Background: Acute appendicitis is a complex diagnosis that often requires both clinical and radiological evaluation. Significant variations in diagnostic approaches are evident among clinicians and healthcare institutions. While certain guidelines advocate for risk stratification based on clinical characteristics, others emphasize the importance of pre-operative imaging. This study seeks to explore the accuracy of the Alvarado Score and abdominal ultrasound (AUS) in diagnosing acute appendicitis.

Methods: Suspected cases of appendicitis admitted to Al-Thora Hospital in Ibb, Yemen, from Jan 2021 to July 2022 were evaluated. The demographics, clinical, and laboratory data were collected and analyzed. This study assessed Alvarado scores (calculated based on clinical evaluation and laboratory data) and pre-operative AUS findings, correlating them with post-operative and histopathology findings. The Alvarado scores and AUS sensitivity, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV) were assessed using the ROC curve.

Results: Out of 1021 cases of acute abdomen, 171 patients were suspected of appendicitis. Using AUS along with the Alvarado score, appendicitis was presumed in 137 patients who underwent appendectomy. 130 (94.9%) patients had positive intraoperative and histopathology findings while 7 (5.1%) had negative findings. The Alvarado Score had a sensitivity and specificity of 94.62% and 87.80% at cutoffs of 6, respectively [Area under the curve (AUC): 0.985; 95% confidence interval (CI), 0.954 to 0.998; $p < 0.0001$]. Abdominal US showed a sensitivity of 98.46% and specificity of 82.93% (AUC:0.907; 95% CI, 0.853 to 0.946; $p < 0.0001$).

Conclusion: Alvarado's score and AUS exhibited high sensitivity and specificity in diagnosing acute appendicitis. The substantial accuracy and efficacy of both the Alvarado score and AUS support their utilization as primary investigative tools in resource-limited settings. This approach can help avoid unnecessary appendectomies and minimize the financial burden on patients.

Plain Language Summary: Acute appendicitis poses a diagnostic challenge, with a high rate of false-positive cases identified post-operatively. Computed tomography has been recommended by several surgical societies; however, it is limited by unaffordability and unavailability. Herein, we utilized the Alvarado score along with abdominal ultrasound as an alternative accurate, and cost-effective diagnostic approach. In this study, the negative appendectomy rate was 5.1%. The sensitivity of abdominal ultrasound in detecting appendicitis was 98.5%, with a specificity of 82.9%. The positive predictive value, negative predictive value, and accuracy were determined to be 94.8%, 94.4%, and 94.7%, respectively. The mean Alvarado score was 6.9±2.4, with a sensitivity and specificity of 97.81% and 97.06% at cutoffs of 6, respectively. The area under the curve values of the ROC curve for Alvarado's and abdominal ultrasound were 0.985 (95% CI, 0.954 to 0.998) and (AUC:0.907; 95% CI, 0.853 to 0.946), which was statistically significant ($p < 0.0001$).

Keywords: Acute appendicitis, Alvarado's score, sensitivity, specificity, ultrasound

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Introduction

The estimated lifetime risk of acute appendicitis is 7–8% which renders it one of the most commonly encountered surgical emergencies and the most common indication of emergent surgery worldwide.[1] Notwithstanding its high incidence, acute appendicitis poses a diagnostic challenge with the symptomatic overlap with other causes of acute abdomen. Moreover, the limited sensitivity and specificity of the clinical findings further complicate the diagnostic accuracy of acute appendicitis, which requires early recognition as the delayed diagnosis has been linked to increased mortality and morbidity, particularly among children and older individuals.[2,3]

To aid in the diagnosis, several scoring systems have been developed to estimate the probability of acute appendicitis. These include appendicitis inflammatory response (AIR), Raja Isteri Pengiran Anak Saleha Appendicitis (RIPASA), or Alvarado's score.[4] Despite the limitations that entailed these scoring systems, they have been shown to decrease imaging, hospitalizations, and false-positive appendectomies.[5] Alvarado's score remains the most commonly used,[4] and was implemented in the current study.

Prior to the implementation of imaging, post-operative negative appendectomies had a prevalence exceeding 20%, which was deemed acceptable to minimize perforation risk.[6–8] Several reports have shown higher diagnostic accuracy with modalities including abdominal ultrasonography (US), computed tomography (CT), and magnetic resonance imaging (MRI) in evaluating acute appendicitis.[9,10] Nevertheless, the use of CT or MRI might be limited by availability, affordability, or contrast exposure.[11] Abdominal US has been proposed as a method for detecting acute appendicitis. The lack of radiation exposure, widespread availability, and cost-effectiveness are significant advantages of US over other modalities.[12] However, the diagnostic performance of abdominal US shows variable outcomes across diverse studies, with sensitivity ranging from 44% to 100% and specificity from 47% to 99% in diagnosing acute appendicitis.[13] This variability is partly attributed to factors such as operator proficiency, patient adiposity, and the presence of intestinal gaseous contents.[13] While delayed recognition or missed diagnosis of acute appendicitis can lead to suboptimal patient care, higher complication rates, and legal claims, overdiagnosis can risk patients undergoing unnecessary surgical intervention. This study aims to investigate the diagnostic accuracy of abdominal US and the Alvarado score in diagnosing acute appendicitis in a resource-limited setting to reduce negative appendectomy rates.

Materials and Methods

Study Design and Inclusion Criteria

From January 2021 to July 2022, a retrospective cross-sectional study was conducted at Al-Thawra Hospital in Yemen on individuals (greater than 13 years) who arrived at the emergency room with acute abdominal pain and suspected acute appendicitis based on clinical suspicion and/or abdominal US. Among 1021 cases who visited our emergency department with chief complaints of abdominal pain, 171 cases were suspected of appendicitis based on clinical suspicion and/or abdominal US and were included in our analysis. Ethical approval for the study was obtained from the ethics committees of IBB University (ID: IBBUNI.AC.YEM.2022.119), and we conducted the study following the Helsinki Declaration.

Exclusion Criteria

Patients with no documented Alvarado score or who did not have an abdominal ultrasound, pregnant patients, patients aged less than 13 years, patients taking nonsteroidal anti-inflammatory drugs, and those who had been treated recently for urinary tract infection or pelvic inflammatory disease were excluded.

Study Protocol and Outcome

The patients' demographics, including age, gender, residency, body mass index, past medical history, physical examination findings, and laboratory data (complete blood count, blood sugar, viral markers, liver function test, and renal function test), were collected along with corresponding Alvarado's scores (Table 1). The duration of symptoms was calculated from the onset of symptoms to hospitalization. Regarding the abdominal US, experienced radiologists performed all abdominal ultrasonography utilizing a graded compression approach and a 5.0-MHz linear array transducer. Positive US results for appendicitis were defined as the presence of an enlarged non-compressible appendix with an

Table 1 Alvarado Score

Variables	Clinical Features	Score
Symptoms	Migratory RIF pain	1
	Anorexia	1
	Nausea and vomiting	1
Signs	Tenderness RIF	2
	Rebound tenderness	1
	Elevated temperature	1
Laboratory	Leukocytosis	2
	Shift to left	1
Total Score	–	10

outer wall diameter greater than 6 mm, a complex mass, or an appendicolith. Reports lacking these suggestive findings or including acute appendicitis solely as a potential differential diagnosis without a higher probability were deemed negative for appendicitis. These definitions were implemented from prior studies.[14,15] Among patients who underwent appendectomy, a histopathological examination of acute appendicitis was considered confirmatory, and it was associated with individual Alvarado's scores and US findings. Patients who did not undergo surgery, based on low Alvarado score probability or lack of suggestive abdominal US findings were followed for one week and 1 month after their discharge from the hospital.[15]

Statistical Analysis

The categorical variables were described using frequencies and percentages. For continuous variables, the mean ±SD was determined. Independent *t*-tests were conducted for normal data, whereas the Mann–Whitney test was employed for non-normal data. The sensitivity, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV) of US and Alvarado's score in determining acute appendicitis were analyzed using respective formulas and the area under the receiver operating characteristic (ROC) curve, and the appropriate cut-off for Alvarado's scores was presented separately. A p-value < 0.05 was considered to be statistically significant. IBM SPSS version 22 (Armonk, IBM Corp, Armonk, NY) was used for data analysis.

Results

Among 1021 patients who presented with acute abdomen, 171 cases were provisionally diagnosed as acute appendicitis. Of these, 135 were identified by Abdominal US as positive for appendicitis, while 36 were deemed negative (2 of these were incorrectly classified as negative by Abdominal US). A total of 137 patients underwent open appendectomy, with 130 (94.9%) having positive intraoperative and histopathological Results, and 7 (5.1%) being diagnosed as negative. The main age of patients was 24.9 ±11.5 (range 18–72 years). Most of the cases were male (71.9%) and live in rural areas (52.6%). Smoking and khat chewing were reported in 30 (17.5%) and 122 (71.3%) of the cases respectively (Table 2).

Alvarado Score Result

The mean Alvarado's score was 6.9 ±2.4, with 57.9% of patients having Alvarado's score of ≥7. According to a cutoff point of 6, the sensitivity of Alvarado's score in detecting appendicitis was 94.62%, with a specificity of 87.80%. The PPV, NPV, and Area under the curve (AUC) were determined to be 96.09%, 83.72%, and 0.938, CI: 0.954 to 0.998, respectively (recommended for "ruling in" appendicitis and progression to surgery). According to a cutoff point of 5, the sensitivity of Alvarado's score in detecting appendicitis was 98.46%, with a specificity of 82.93% (ruling out' admission for appendicitis). The PPV and NPV were determined to be 94.81%, 94.44%, and 0.938, respectively.

Table 2 Demographic and Clinical Information of Participants

Variables	Subgroup	Total (N=171)	Discharged Without Surgery (N=34)	Underwent Appendectomy (N=137)	p-value
Age (year)	Mean ±SD	24.9 ±11.5	20.9 ±7.0	25.8 ±12.2	**0.023**
Gender	Male	123 (71.9)	27 (79.4)	96 (70.1)	0.383
	Female	48 (28.1)	7 (20.6)	41 (29.9)	
Body mass index	Normal	147 (86.0)	33 (97.1)	114 (83.2)	0.071
	Overweight	24 (14.0)	1 (2.9)	23 (16.8)	
Smoking	No	141 (82.5)	27 (79.4)	114 (83.2)	0.788
	Yes	30 (17.5)	7 (20.6)	23 (16.8)	
Residency	Unknown	1 (0.6)	0 (0.0)	1 (0.7)	0.883
	Rural	90 (52.6)	18 (52.9)	72 (52.6)	
	Urban	80 (46.8)	16 (47.1)	64 (46.7)	
Khat chewing habitus	No	49 (28.7)	8 (23.5)	41 (29.9)	0.598
	Yes	122 (71.3)	26 (76.5)	96 (70.1)	
Duration of symptoms	Mean ±SD	24.1 ±23.1	27.8 ±30.4	23.2 ±20.9	0.292
Previous pain attack	No	166 (97.1)	33 (97.1)	133 (97.1)	1.000
	Yes	5 (2.9)	1 (2.9)	4 (2.9)	
Alvarado's score	Mean ±SD	6.9 ±2.4	3.3 ±0.9	7.8 ±1.8	**<0.001**
Alvarado's score subgroups	4 and less	36 (21.1)	33 (97.1)	3 (2.2)	**<0.001**
	5–6	36 (21.1)	1 (2.9)	35 (25.5)	
	7 or above	99 (57.9)	0 (0.0)	99 (72.3)	
Ultrasound	Negative	36 (21.1)	34 (100.0)	2 (1.5)	**<0.001**
	Positive	135 (78.9)	7 (17.1)	128 (98.5)	

Note: Boldface indicates a statistically significant result (P< 0.05).

The ROC curve for Alvarado's score showed significant AUC values for detecting acute appendicitis and was statistically significant [95% Confidence interval (CI): 0.891 to 0.969; p< 0.0001] (Figure 1A).

Ultrasound Results

Based on the pre-specified criteria, 135 patients were classified by abdominal US as positive for appendicitis, and 36 patients were considered negative (of them 2 cases were incorrectly negative by abdominal US). Open appendectomy was performed in 137 patients, of which 130 (94.9%) had positive intraoperative findings and histopathological results while 7 (5.1%) patients were diagnosed negative (Table 3). The sensitivity of abdominal US in detecting appendicitis was 98.46%, with a specificity of 82.93%. The PPV, NPV, and AUC were determined to be 94.81%, 94.44%, and 0.907, respectively. The ROC curve for the abdominal US showed significant AUC values for detecting acute appendicitis and was statistically significant (95% CI: 0.853 to 0.946; p < 0.0001) (Figure 1B).

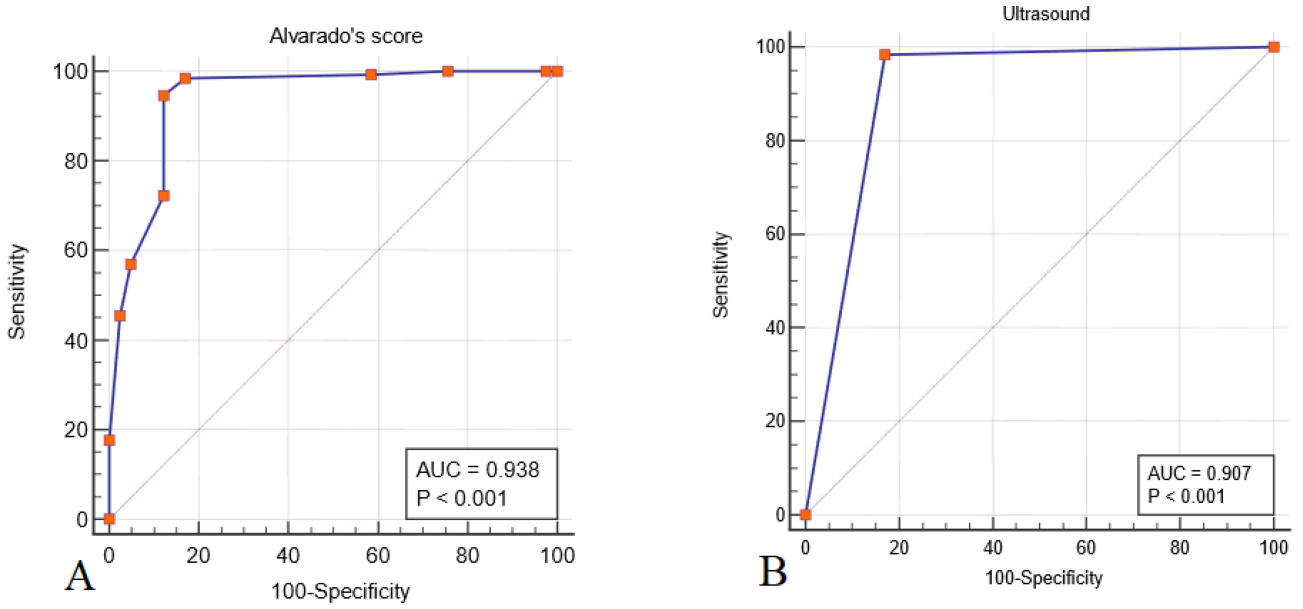

Figure 1 Sensitivity, Specificity, and AUC of Alvarado Score in subfigure; the Area under the curve (AUC) for the ROC curve of Alvarado Score was 0.985 with a 95% confidence interval (CI), 0.954 to 0.998, and was statistically significant ($p < 0.0001$) (**A**) and abdominal ultrasound; The Area under the curve (AUC) for the ROC curve of Abdominal US was 0.907 with a 95% CI, 0.853 to 0.946, and was statistically significant ($p < 0.0001$) (**B**).

Discussion

The reliance on patients' clinical assessment for diagnosing acute appendicitis may result in delayed recognition or intervention.[16] Classic symptoms, such as periumbilical pain with migration or shifting to the right lower quadrant, are reported only in about 50% of patients. These symptoms have similar or even lower sensitivity and specificity compared to several historic physical signs of appendicitis.[6,7] Furthermore, the practice of mandatory surgical exploration for suspected appendicitis has led to a heightened incidence of negative appendectomies, with rates considered acceptable up to 25% in the general population and up to 50% during pregnancy.[6,7] Nevertheless, retrospective reports have shown increased morbidity and mortality with negative appendectomies, making such practices less favorable.[17,18]

In this study, we evaluated the role of abdominal US and Alvarado score in establishing the diagnosis of acute appendicitis. This approach was chosen due to the affordability and availability of US in our setting. Notably, abdominal US showed a high sensitivity of 98.46% in detecting appendicitis, with a specificity of 82.93%. Its PPV, NPV, and AUC were 94.81%, 94.44%, and 0.907. There is a notable variation in the sensitivity and specificity of abdominal US reported in the literature. For instance, Hosseini et al reported a sensitivity and specificity of 58% and 68%, respectively.[16] Conversely, Abu-Yousef et al reported higher sensitivity (80%) and specificity (95%).[14] These findings, when taken together, might indicate methodological differences attributed to study settings and radiological expertise. While pooling studies were thought to provide more precise findings, there is notable heterogeneity in the literature that might limit this effect. For instance, a meta-analysis by Orr et al showed a sensitivity and specificity of 84.7% and 92.1%, respectively. Nevertheless, US performance was noted to be related to the pre-test probability of acute appendicitis, with a high PPV

Table 3 Total Diagnosed Cases by Abdominal Ultrasound

Ultrasonography	Intraoperative Findings		Total
	Acute Appendicitis	Normal	
Acute appendicitis	128 (98.5%)	7 (17.0%)	135
Normal	2 (1.5%)	34 (83.0%)	36
Total	130 (76.0%)	41(24.0%)	171

among patients with a high likelihood of having acute appendicitis. The authors concluded that US should not be used to exclude appendicitis given the poor NPV.[10] Conversely, a recent meta-analysis that included 21 studies reported a pooled sensitivity and specificity of 81% and 87%, respectively.[19] While the subgroup analysis was similar, there was noted heterogeneity and a risk for publication bias.

Understandably, the clinician's expertise might be a significant factor in the study outcome, which might be difficult to control with cases that require urgent evaluation as acute appendicitis. This was particularly evident in Hosseini et al and Pinto et al which showed lower US sensitivity and specificity based on the operator performance.[13,16]

Scoring systems for acute appendicitis are of long use and have been utilized for diagnostic and risk stratification purposes. Several scores have been introduced, including appendicitis inflammatory response (AIR), and Raja Isteri Pengiran Anak Saleha Appendicitis (RIPASA).[4] Nevertheless, the Alvarado Score is the most extensively studied and utilized in clinical practice. This score is primarily based on symptoms, clinical finding, and laboratory results, offering a considerably sensitive method for identifying individuals with probable acute appendicitis.[20] In this study, Alvarado's score has a sensitivity of 94.62% in detecting appendicitis, with a specificity of 87.80%. Its PPV, NPV, and AUC values are 96.09%, 83.72%, and 0.938, respectively. The ROC curve for Alvarado's score shows significant AUC values for detecting acute appendicitis. Our inclusion of Alvarado's score in this study was based on the remarkably high sensitivity and specificity reported in the literature.[21] Indeed, consensus from international guidelines has recommended the use of Alvarado's score in the diagnostic evaluation of acute appendicitis.[12,22] A meta-analysis by Gupta et al demonstrated a high predictability of the Alvarado score in acute appendicitis.[23] Our findings align with the study by Kanumba et al, which reported Alvarado score sensitivity, specificity, PPV, NPV, and accuracy of 94.1%, 90.4%, 95.2%, and 88.4%, respectively.[24] In the study by Memon et al, the Alvarado scoring system exhibited high sensitivity and specificity at 93.5% and 80.6%, with PPV and NPV at 92.3% and 83.3%, respectively, and an accuracy of 89.8%.[25] Notwithstanding the benefits of the Alvarado score in limiting the overutilization of imaging modalities, especially in limited-resource settings, these remarkable findings need to be approached with caution. There is noticeable variability in the cutoff used to indicate significant sensitivity and specificity of the Alvarado score.[26] Furthermore, there is a low reproducibility rate of several parameters used in the Alvarado score that might limit the certainty of the evaluation.[4] Nevertheless, the role of the Alvarado score might be significant in ruling out the diagnosis of acute appendicitis with a low cutoff, a conclusion endorsed in a meta-analysis by Ohle et al.[27] The authors, however, reported an overestimation of the Alvarado score among female patients. In a recent clinical trial by Noori et al, the significance of high clinical scores in warranting surgical intervention was underscored.[28] Interestingly, clinical scores performance exceeded the performance of the US in our study.

While the Alvarado score can provide substantial diagnostic value, it is crucial to recognize its limitations. For instance, several reports have shown suboptimal performance in the pediatric age group. In a recent meta-analysis of 26 studies involving 5985 children from 11 countries, the Alvarado score had a combined sensitivity of 76.0% and a combined specificity of 71.0% for diagnosing acute appendicitis in children, while the modified Alvarado score had a combined sensitivity of 87.0% and a combined specificity of 47.0%.[29] Additionally, the Alvarado score has been noted to overestimate the probability of appendicitis in females,[27] and poorly identify complicated appendicitis in the elderly population.[30] Further studies are needed to address these drawbacks and develop a possible calibration that accounts for patients' gender and age.

This study has several limitations attributed to its retrospective design and the small sample size, which may introduce confounding biases. In addition, the lack of a control group limits the generalizability of our findings. Furthermore, the reliance on medical records may further introduce the risk of selection and misclassification biases, which influence documentation quality.

Conclusion

Alvarado's score and abdominal ultrasound exhibited high sensitivity and specificity in diagnosing acute appendicitis. The substantial accuracy and efficacy of both the Alvarado score and abdominal ultrasound support their utilization as primary investigative tools in resource-limited settings. This approach can help avoid unnecessary appendectomies and minimize the financial burden on patients.

Data Sharing Statement

The datasets used and analyzed during the current study are available from the corresponding author (Faisal Ahmed) upon reasonable request.

Ethics Approval and Consent to Participate

The Ibb University's ethics committee approved the study protocol and all patients provided informed consent before enrolment and the study complies with the Declaration of Helsinki.

Consent for Publication

All authors reviewed the manuscript and approved its submission.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors declare that they have no competing interests in this work.

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