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Assessing the Diagnostic Precision of Abdominal Ultrasonography and the Alvarado Score for Acute Appendicitis

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Abstract

Background: Acute appendicitis is a common surgical emergency with a lifetime risk of 7–8%. However, its diagnosis remains challenging due to symptom overlap with other abdominal conditions. Clinical tools like the Alvarado score and imaging methods such as abdominal ultrasonography (US) are often used to improve diagnostic accuracy. This study aims to evaluate the diagnostic performance of the Alvarado score and abdominal US for diagnosing acute appendicitis.

Methods: This study was conducted including 200 patients aged 13 years and older who presented with acute abdominal pain and were suspected of having acute appendicitis. The Alvarado score and abdominal US were used to assess diagnostic accuracy, with histopathological examination serving as the gold standard for confirmed diagnoses. Diagnostic metrics such as sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and area under the receiver operating characteristic (ROC) curve were calculated.

Results: The Alvarado score demonstrated high sensitivity (94.62%) and specificity (87.80%), with a positive predictive value (PPV) of 96.09% and a negative predictive value (NPV) of 83.72%. Abdominal US showed a sensitivity of 98.46% and specificity of 82.93%, with a PPV of 94.81% and an NPV of 94.44%. The area under the ROC curve (AUC) for both the Alvarado score and abdominal US was 0.938 and 0.907, respectively.

Conclusion: Both the Alvarado score and abdominal ultrasound demonstrated high diagnostic accuracy in diagnosing acute appendicitis. These tools are particularly useful in resource-constrained settings, helping to minimize unnecessary surgical procedures and reducing healthcare costs.

Introduction

Acute appendicitis is a prevalent surgical emergency, with an estimated lifetime risk of 7–8%, making it one of the most frequently encountered conditions requiring urgent surgical intervention worldwide (1). Despite its common occurrence, diagnosing acute appendicitis remains challenging due to its symptom overlap with other abdominal conditions. Additionally, the limited sensitivity and specificity of clinical symptoms can hinder accurate diagnosis, necessitating prompt identification to avoid complications. Delayed diagnosis is associated with increased risks of morbidity and mortality, particularly among vulnerable groups such as children and the elderly (2,3).

To improve diagnostic precision, various scoring systems have been developed to estimate the likelihood of acute appendicitis, including the appendicitis inflammatory response (AIR), Raja

Isteri Pengiran Anak Saleha Appendicitis (RIPASA), and Alvarado scoring systems (4). Although these tools have limitations, they have proven effective in reducing the use of imaging, unnecessary hospital admissions, and false-positive appendectomies (5). Among these, the Alvarado score is the most widely utilized and was employed in this research (4).

Before imaging became routinely implemented, the rate of negative appendectomies exceeded 20%, a figure historically considered acceptable to mitigate the risk of perforation (6–8). With advancements in diagnostic modalities, imaging techniques such as abdominal ultrasonography (US), computed tomography (CT), and magnetic resonance imaging (MRI) have shown improved accuracy in diagnosing acute appendicitis (9,10). However, the utility of CT and MRI can be limited by factors such as cost, availability, and potential contrast exposure (11).

Abdominal US has emerged as an alternative diagnostic tool with advantages like the absence of radiation, widespread accessibility, and cost-effectiveness (12). However, its diagnostic reliability varies significantly across studies, with sensitivity reported between 44% and 100% and specificity ranging from 47% to 99% (13). This variability is influenced by factors such as operator expertise, patient body composition, and the presence of intestinal gas (13). While delayed or missed diagnoses of acute appendicitis can lead to serious complications and legal ramifications, overdiagnosis can result in unnecessary surgical procedures.

This study evaluates the diagnostic performance of abdominal US and the Alvarado score in diagnosing acute appendicitis, particularly in resource-constrained environments, with the aim of minimizing negative appendectomy rates.

Materials and Methods

This study employed 200 Participants included individuals aged 13 years and older who presented with acute abdominal pain and were clinically suspected of having acute appendicitis, either based on clinical evaluation or findings from abdominal ultrasonography (US). Out of 1500 patients who visited the emergency department with abdominal pain during this timeframe, 200 cases were identified as suspected appendicitis and subsequently included in the analysis.

Exclusion Criteria

Patients were excluded if they lacked documented Alvarado scores or abdominal US results, were pregnant, younger than 13 years, had recently used nonsteroidal anti-inflammatory drugs, or had been treated for urinary tract infections or pelvic inflammatory disease.

Study Protocol and Outcome

Demographic information such as age, gender, residency, body mass index, and relevant clinical data including medical history, physical examination findings, and laboratory test results (complete blood count, blood sugar, viral markers, liver function tests, and renal function tests) were collected. Alvarado scores for all participants were calculated . Symptom duration was measured from onset to hospital admission.

Abdominal US examinations were performed using a graded compression technique with a 5.0-MHz linear array transducer, carried out by trained radiologists. Positive findings for appendicitis on US were defined as an enlarged non-compressible appendix with an outer wall diameter greater than 6 mm, an appendicolith, or a complex mass. Reports that lacked these criteria or merely listed appendicitis as a differential diagnosis without strong evidence were categorized as negative. These criteria were based on prior studies (14,15).

For patients who underwent appendectomy, the diagnosis was confirmed via histopathological examination, which was correlated with their Alvarado scores and US findings. Patients with low Alvarado scores or negative US findings who were not treated surgically were monitored at one-week and one-month intervals after discharge to ensure the absence of unresolved appendicitis (15).

Statistical Analysis

Categorical variables were expressed as frequencies and percentages, while continuous variables were summarized as mean ± standard deviation (SD). Independent t-tests were used for data following a normal distribution, whereas the Mann–Whitney U test was applied for non-normal distributions. Diagnostic metrics including sensitivity, specificity, accuracy,

positive predictive value (PPV), and negative predictive value (NPV) for US and Alvarado scores in diagnosing acute appendicitis were calculated. Additionally, the area under the receiver operating characteristic (ROC) curve was analyzed, and the optimal cut-off value for Alvarado scores was identified. Statistical significance was defined as a p-value < 0.05. Data were analyzed using IBM SPSS version 22 (Armonk, IBM Corp).

Results

Out of 1500 patients presenting with acute abdominal pain, 200 were initially suspected of having acute appendicitis. Among these, abdominal ultrasonography (US) identified 135 cases as positive for appendicitis, while 36 cases were classified as negative, including 2 instances that were later determined to be false negatives. A total of 137 patients underwent open appendectomy, with 130 cases (94.9%) confirmed as acute appendicitis based on intraoperative findings and histopathological examination, while 7 cases (5.1%) were negative. The average age of patients was 24.9 ± 11.5 years, ranging from 18 to 72 years. A majority of the cases were male (71.9%), and 52.6% resided in rural areas.

The average Alvarado score among patients was 6.9 ± 2.4, with 57.9% scoring ≥7. Using a cutoff value of 6, the Alvarado score demonstrated a sensitivity of 94.62% and a specificity of 87.80% for diagnosing acute appendicitis. The positive predictive value (PPV), negative predictive value (NPV), and area under the receiver operating characteristic curve (AUC) were 96.09%, 83.72%, and 0.938 (confidence interval [CI]: 0.954–0.998), respectively. This cutoff was recommended for confirming appendicitis and proceeding with surgical intervention. At a cutoff value of 5, the sensitivity increased to 98.46%, while the specificity decreased to 82.93%. Corresponding PPV and NPV values were 94.81% and 94.44%, with the same AUC value of 0.938.

Abdominal US identified 135 patients as positive for appendicitis, while 36 were classified as negative, including 2 cases inaccurately labeled as false negatives. Among the 137 patients who underwent open appendectomy, intraoperative and histopathological analysis confirmed acute appendicitis in 130 cases (94.9%), whereas 7 cases (5.1%) were deemed negative (Table 1). The sensitivity and specificity of abdominal US in diagnosing appendicitis were 98.46% and 82.93%, respectively. The PPV, NPV, and AUC for abdominal US were calculated to be 94.81%, 94.44%, and 0.907, respectively.

Table 1. Total Diagnosed Cases by Abdominal Ultrasound

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

Discussion

Relying solely on clinical assessment to diagnose acute appendicitis can lead to delays in identifying or treating the condition (16). Classic symptoms such as periumbilical pain migrating to the right lower quadrant are observed in only about half of the patients. These symptoms demonstrate comparable or lower diagnostic sensitivity and specificity than many traditional physical signs associated with appendicitis (6, 7). Moreover, the practice of performing surgery on all suspected appendicitis cases has resulted in an elevated number of unnecessary appendectomies, with acceptable negative appendectomy rates reported up to 25% in general populations and as high as 50% during pregnancy (6, 7). However, retrospective studies suggest that negative appendectomies are associated with increased risks of complications, making such an approach less desirable (17, 18).

This study aimed to evaluate the effectiveness of abdominal ultrasound (US) and the Alvarado scoring system in diagnosing acute appendicitis. The preference for US stems from its cost-effectiveness and availability in the study setting. In this research, abdominal US demonstrated a sensitivity of 98.46% and a specificity of 82.93%, with positive predictive value (PPV), negative predictive value (NPV), and area under the receiver operating characteristic curve (AUC) values of 94.81%, 94.44%, and 0.907, respectively. However, the diagnostic accuracy

of abdominal US varies across studies. For instance, sensitivity and specificity were reported at 58% and 68% by one study (16), while another study documented higher values of 80% and 95%, respectively (14). Meta-analyses also show variation; for example, Orr et al. reported pooled sensitivity and specificity of 84.7% and 92.1%, whereas another review found values of 81% and 87% (10, 19). This variability may reflect differences in methodology, patient populations, and operator expertise, as evidenced by studies attributing lower diagnostic performance to operator-dependent factors (13, 16).

Scoring systems such as the appendicitis inflammatory response (AIR) and the Raja Isteri Pengiran Anak Saleha Appendicitis (RIPASA) score have been used for risk stratification and diagnosis (4). However, the Alvarado score remains the most widely studied and utilized tool in clinical settings. It combines symptomatology, clinical findings, and laboratory results to provide a reliable method for assessing suspected appendicitis cases. This study found that the Alvarado score had a sensitivity of 94.62% and a specificity of 87.80%, with PPV, NPV, and AUC values of 96.09%, 83.72%, and 0.938, respectively. These findings align with those of earlier research, such as studies reporting comparable sensitivity, specificity, and predictive values (24, 25). While international guidelines endorse the Alvarado score for diagnosing acute appendicitis (12, 22), variations in cutoff values and low reproducibility of some parameters might affect its reliability (4, 26). Additionally, a meta-analysis highlighted overestimation in female patients and underperformance in specific populations (27).

Despite its advantages, the Alvarado score has certain limitations. For example, its diagnostic accuracy in pediatric cases is suboptimal. A meta-analysis involving 26 studies and nearly 6,000 children reported combined sensitivities and specificities of 76.0% and 71.0%, respectively, while a modified Alvarado score showed improved sensitivity (87.0%) but reduced specificity (47.0%) (29). The score is also less effective in identifying complicated cases in older patients and tends to overestimate appendicitis probability in females (27, 30). Future research should address these issues by refining the score to account for age and gender differences.

This study's retrospective nature and small sample size are key limitations, potentially introducing biases related to confounding factors, selection, and misclassification. Additionally, the absence of a control group restricts the applicability of the findings to broader populations.

Conclusion

Both the Alvarado score and abdominal ultrasound demonstrated high sensitivity and specificity in diagnosing acute appendicitis. Their accuracy and cost-effectiveness support their use as primary diagnostic tools, particularly in resource-limited environments. This approach can help reduce unnecessary surgical interventions and alleviate financial burdens on patients.

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