ORIGINAL ARTICLE

# COMPARATIVE ANALYSIS OF THE DIAGNOSTIC ACCURACY OF THE APPENDICITIS INFLAMMATORY RESPONSE SCORE AND THE ALVARADO SCORE IN ACUTE APPENDICITIS USING HISTOPATHOLOGY AS THE GOLD STANDARD

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## ABSTRACT

**Objectives:** To compare the diagnostic accuracy of the Alvarado Score and the Appendicitis Inflammatory Response (AIR) Score in patients presenting with suspected acute appendicitis, using histopathological findings as the gold standard.

**Study Design:** Comparative cross-sectional validation study.

**Place and Duration of Study:** The study was conducted at Surgical Unit III, Allama Iqbal Memorial Teaching Hospital, Sialkot, from November 20, 2024, to May 20, 2025.

**Methodology:** A total of 205 patients aged 18–70 years presenting with clinical signs of acute appendicitis were included using non-probability consecutive sampling. Each patient's Alvarado and AIR scores were calculated based on clinical, laboratory, and radiological findings. All patients underwent appendectomy, and the removed specimens were examined histopathologically. Diagnostic performance was evaluated by calculating sensitivity, specificity, positive and negative predictive value (PPV, NPV), positive and negative likelihood ratio, and overall accuracy using SPSS ver. 26.0.

**Results:** Among patients (63.4% male, mean age 28.04 ± 4.17 years), histopathology confirmed acute appendicitis in 161 (78.5%). The Alvarado Score showed 92.55% sensitivity, 97.73% specificity, and 93.66% accuracy, while the AIR Score had 88.20% sensitivity, 97.73% specificity, and 90.24% accuracy.

**Conclusion:** The Alvarado and AIR Scores are reliable for diagnosing acute appendicitis, with the Alvarado Score slightly outperforming in sensitivity and accuracy. The Alvarado Score may be preferred in emergency settings for efficient diagnosis and management.

***Keywords:*** Acute appendicitis, Alvarado Score, Appendicitis Inflammatory Response (AIR) Score, diagnostic accuracy, histopathology, sensitivity, specificity

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## INTRODUCTION

Medical concerns regarding acute appendicitis are widespread, and in 2019 alone, approximately 17.7 million cases were reported globally, with an incidence rate of 228 cases per 100,000 people.[1] Appendicitis is difficult to diagnose, especially in children, the elderly, and reproductive-aged females, because symptoms overlap with those of other conditions. The Alvarado and Appendicitis Inflammatory Response scores have been developed as clinical scoring systems to aid diagnosis. Nevertheless, they have merits and demerits, which need to be researched further in terms of comparative accuracy.[2, 3] A commonly used clinical prediction tool for evaluating the risk of appendicitis is the Alvarado Score, which includes the symptoms, clinical signs, and laboratory results. Its accuracy is widely used; however, it varies notably between women and children, overdiagnosing frequently. Therefore, these limitations were overcome using the AIR score, which included additional clinical indicators of the patient, such as C-reactive protein (CRP). C-reactive protein is a readily available laboratory marker; however, it is insufficiently sensitive and specific. Therefore, the combined performance of the two scoring systems should be evaluated to improve appendicitis diagnosis.[4, 5] The accuracy of Alvarado and AIR scores has been assessed in several studies. Tariq et al. examined the diagnostic accuracy of both scores using histopathology as the gold standard. Their findings revealed that the Alvarado score had a sensitivity of 80.1%, a specificity of 92.3%, and an accuracy of 81.7%. The AIR score, however, had slightly lower sensitivity (72.6%) but higher specificity (94.2%), with an overall accuracy of 75.5%.[6] Jose and Rajesh's research indicated the superiority of the AIR score. The sensitivity and specificity of the Alvarado score were 72% and 79%, respectively, and the AIR scores were 98% and 97%, respectively, suggesting better performance in discriminating true patients with appendicitis.[7]

Advancements in scoring systems and diagnostic methods have mitigated the diagnostic difficulty in most patients with acute appendicitis; however, acute appendicitis in a selected population remains a diagnostic challenge. Studies have suggested good results with the Alvarado and AIR scores, but comparisons between the two are inconsistent across different settings and patient groups. The Alvarado score is believed to be more reliable than the AIR score. Thus, a study performed at the Allama Iqbal Memorial Teaching Hospital, Sialkot, is required to gain locally relevant insights because of these discrepancies. The objective of this study was to assess the accuracy of the AIR and Alvarado scores. Clinicians can evaluate the performance of appendicitis diagnosis systematically, thus determining its reliability in diagnosing appendicitis. The findings of this study could make a big difference to physicians' clinical decision-making by informing them which scoring system they should use in emergency circumstances. This will lead to enhanced diagnostic accuracy, improved patient care, decreased number of unnecessary surgeries, and effective utilisation of resources, resulting in better management of acute appendicitis.

## METHODS

The comparative cross-sectional validation study was conducted in the Allama Iqbal Memorial Teaching Hospital, Sialkot, at surgical unit III from 20th November 2024 to 20th May 2025 after approval from the College of Physicians and Surgeons Pakistan via letter CPSP/REU/SGR-2022-150-14572 dated 15th November 2024. The study involved 205 patients selected via non-probability consecutive sampling, calculated with a 95% confidence level and 13% margin of error, demonstrating a 72.6% prevalence of acute appendicitis,[6] with modified Alvarado score yielding 64.44% sensitivity and 58.82% specificity against histopathology as the gold standard.[8] Patients (aged between 18 and 70 years) of both genders, ASA class I or II, who had pain in the right iliac fossa and presented with acute appendicitis, for the likely reason for acute appendicectomy, were included. Patients with chronic abdominal pain and those without a histopathological report of the resected specimen during follow-up were excluded. All the participants provided informed consent. Demographic and clinical baseline information, including age, sex, BMI, and symptom duration, was recorded. Each patient was then evaluated using the Alvarado and AIR scores based on the findings of the physical examination. A score of $\geq 9$ was considered a sign of appendicitis in the AIR score system, and a score of $< 9$ indicated no appendicitis. As with the Alvarado scoring system, it was similar in showing a score of $\geq 7$ as appendicitis and $< 7$ as no appendicitis. A senior consultant with at least five years of experience decides whether surgical intervention is needed. All surgical procedures were performed by a single surgical team using standard protocols. All resected specimens were histopathologically confirmed for diagnosis.

All collected data were analyzed using SPSS ver 26.0. The cases were categorized as true positive, true negative, false positive, and false negative, keeping histopathology as the gold standard. Sensitivity, specificity, positive and negative predictive value, positive and negative likelihood ratio, and overall diagnostic accuracy were then calculated.

## RESULTS

The study included 205 participants with a mean age was 28.04 years (SD = 4.17). The gender distribution showed 130 males (63.4%) and 75 females (36.6%). The mean BMI was 24.54 (SD = 1.74). The mean duration of pain was 17.07 hours (SD = 3.93). For the Alvarado Score, the mean was 7.26 (SD = 1.62), with 150 participants (73.2%) classified as positive and 55 (26.8%) as negative. For the AIR Score, the mean was 9.01 (SD = 1.96), with 143 participants (69.8%) classified as positive and 62 (30.2%) as negative. Histopathological diagnosis revealed 161 positive cases (78.5%) and 44 negative cases (21.5%). Based on the Alvarado Score, the case diagnosis results were: True Positive (TP) = 149 (72.7%), True Negative (TN) = 43 (21.0%), False Positive (FP) = 1 (0.5%), and False Negative (FN) = 12 (5.9%). For the AIR Score, the results were: TP = 142 (69.3%), TN = 43 (21.0%), FP = 1 (0.5%), and FN = 19 (9.3%). The diagnostic performance of the Alvarado score and the AIR score compared to histopathology is presented in Table 1

Table 1: Diagnostic Performance of Alvarado and AIR Scores vs. Histopathology

| Score | Parameter | 95% CI |
|---|---|---|
| Alvarado Score | Sensitivity | 87.34% to 96.09% |
| | Specificity | 87.98% to 99.94% |
| | Positive Likelihood Ratio | 5.86 to 282.82 |
| | Negative Likelihood Ratio | 0.04 to 0.13 |
| | Positive Predictive Value | 95.55% to 99.90% |
| | Negative Predictive Value | 67.48% to 86.09% |
| | Accuracy | 89.40% to 96.58% |
| AIR Score | Sensitivity | 82.19% to 92.74% |
| | Specificity | 87.98% to 99.94% |
| | Positive Likelihood Ratio | 5.59 to 269.63 |
| | Negative Likelihood Ratio | 0.08 to 0.18 |
| | Positive Predictive Value | 95.34% to 99.90% |
| | Negative Predictive Value | 59.68% to 77.58% |
| | Accuracy | 85.33% to 93.94% |

## DISCUSSION

Our study assessed the diagnostic performance of the Alvarado Score and the Appendicitis Inflammatory Response (AIR) Score for acute appendicitis in a cohort of 205 patients (63.4% male, mean age 28.04 ± 4.17 years), using histopathology as the gold standard. The Alvarado Score achieved a sensitivity of 92.55% (95% CI: 87.34%–96.09%), specificity of 97.73% (95% CI: 87.98%–99.94%), positive predictive value (PPV) of 99.33% (95% CI: 95.55%–99.90%), negative predictive value (NPV) of 78.18% (95% CI: 67.48%–86.09%), and accuracy of 93.66% (95% CI: 89.40%–96.58%). The AIR Score demonstrated a sensitivity of 88.20% (95% CI: 82.19%–92.74%), specificity of 97.73% (95% CI: 87.98%–99.94%), PPV of 99.30% (95% CI: 95.34%–99.90%), NPV of 69.35% (95% CI: 59.68%–77.58%), and accuracy of 90.24% (95% CI: 85.33%–93.94%). Both scores exhibited a statistically significant association with histopathological diagnosis ($p < 0.001$).
Chisthi et al. [8] reported a notably lower performance for the Alvarado Score, with a sensitivity of 64.44%, specificity of 58.82%, PPV of 89.23%, NPV of 23.81%, and accuracy of 63.55%. Their AIR Score, however, showed a high sensitivity of 97.78% but a low specificity of 29.41%, with an accuracy of 86.92%. The stark contrast with our findings may be attributed to their focus on a pediatric population, where the AIR Score's reliance on objective variables (e.g., laboratory markers) is advantageous, as children often struggle to articulate subjective symptoms like migratory pain, which the Alvarado Score emphasizes. Our adult cohort likely provided more reliable symptom reporting, enhancing the performance of both scores, particularly the Alvarado Score, which relies heavily on clinical history. Their lower specificity for the AIR Score suggests a higher false-positive rate, potentially leading to unnecessary surgeries, whereas our study's low false-positive rate (0.5% for both scores) underscores the precision of both tools in our setting.
Jose and Rajesh's [7] study found the Alvarado Score to have a sensitivity of 72% and specificity of 79%, while the AIR Score achieved a sensitivity of 98% and specificity of 97%. Their AIR Score's superior sensitivity contrasts with our findings, where the Alvarado Score was more sensitive (92.55% vs. 88.20%). However, our study's specificity for both scores (97.73%) aligns closely with their AIR Score, indicating strong rule-in capability. Differences may stem from variations in cut-off thresholds or patient demographics, as their study does not specify age or gender distribution. Our larger sample size may have contributed to the robust performance of both scores, particularly the Alvarado Score's ability to accurately identify true positives. Tariq et al. [6] reported an Alvarado Score sensitivity of 80.1%, specificity of 92.3%, and accuracy of 81.7%, compared to an AIR Score sensitivity of 72.6%, specificity of 94.2%, and accuracy of 75.5%. Our study's higher sensitivity (92.55% vs. 80.1%) and accuracy (93.66% vs. 81.7%) for the Alvarado Score, and higher sensitivity (88.20% vs. 72.6%) and accuracy (90.24% vs. 75.5%) for the AIR Score, suggest superior diagnostic performance. This may be due to our larger sample size, standardized scoring application, or higher appendicitis prevalence (78.5% vs. potentially lower in their study). Their higher specificity for both scores aligns with our findings, indicating that both tools effectively minimize false positives, though our lower false-positive rate (0.5% vs. implied higher rates) further enhances diagnostic precision. Andersson et al.'s meta-analysis reported an area under the ROC curve (AUC) of 0.86 for the AIR Score and 0.79 for the Alvarado Score, concluding that the AIR Score has better diagnostic capacity. For advanced appendicitis, the AIR Score's AUC was 0.93 compared to 0.88 for the Alvarado Score. Our study's higher accuracy for the Alvarado Score (93.66% vs. 90.24% for AIR) contrasts with their findings, possibly because our study evaluated all appendicitis cases,

whereas their meta-analysis emphasized advanced cases, where the AIR Score's laboratory-based criteria may be more sensitive. Our high specificity (97.73% for both scores) and low false-positive rate align with their reported high specificity for the AIR Score at higher cut-offs (0.98 at >8 points), suggesting both scores are effective at ruling in appendicitis in our cohort.[9]

Safaee et al. found an AUC of 0.81 for the AIR Score and 0.72 for the Alvarado Score, with the AIR Score showing higher sensitivity (96.1% vs. 89.3%) and specificity (82.3% vs. 23.5%) at lower cut-offs (>4). At higher cut-offs (>8), the AIR Score achieved 100% specificity but only 32.1% sensitivity, while the Alvarado Score had 88.2% specificity and 41.7% sensitivity. Our study's higher sensitivity and specificity for both scores at standard cut-offs (e.g., Alvarado >7, AIR >8) indicate better overall performance, likely due to a more homogeneous adult cohort or consistent scoring protocols. Their lower specificity for the Alvarado Score at lower cut-offs suggests a higher false-positive rate, which our study avoided (FP = 0.5%).[10] Hassan et al. reported an AIR Score sensitivity of 77.97% and specificity of 85.71%, compared to 67.80% and 78.57% for the Alvarado Score. Our study's superior performance (e.g., 92.55% sensitivity and 97.73% specificity for Alvarado) may reflect a larger sample size (205 vs. 73) or higher disease prevalence (78.5% vs. 80.8%). Their higher false-positive rate (2 for AIR, 8 for Alvarado) contrasts with our minimal false positives (1 for both scores), highlighting our study's precision in identifying true negatives.[11] Paracha et al. found an Alvarado Score sensitivity of 64.70% and specificity of 88.23%, and an AIR Score sensitivity of 70.58% and specificity of 94.11%, with AUCs of 0.64 and 0.70, respectively. Our study's higher sensitivity and specificity for both scores suggest stronger diagnostic utility, possibly due to our higher prevalence (78.5% vs. ~56%) or larger sample. Their lower sensitivity indicates a higher false-negative rate, whereas our study's low false-negative rates (5.9% for Alvarado, 9.3% for AIR) enhance rule-out capability.[12]

Farooq et al. reported an Alvarado Score sensitivity of 94.1% but a specificity of 33.3%, with an accuracy of 85%. Our Alvarado scores' comparable sensitivity (92.55%) and markedly higher specificity (97.73%) suggest better rule-in and rule-out performance. Their low specificity likely increased false positives, whereas our study's low false-positive rate (0.5%) minimized unnecessary surgeries.[13] Syed et al. found an Alvarado Score sensitivity of 83.3% and specificity of 72.2%, lower than our 92.55% and 97.73%. Their focus on a resource-limited setting with a higher negative appendectomy rate (inferred from moderate specificity) contrasts with our controlled environment, where standardized scoring likely improved performance. Their subgroup analysis showing better performance in males and younger adults (18–30 years) aligns with our predominantly male (63.4%) and young (mean age 28.04) cohort, potentially explaining our high performance.[14]

Abouelnour et al. reported the Alvarado Score as the most sensitive (91% at cut-off >4), followed by the Adult Appendicitis Score (AAS) (80%) and AIR Score (71%). In females, the Alvarado Score's sensitivity was 95%, significantly higher than the AIR Score's 70%. Our study's high Alvarado Score sensitivity (92.55%) and specificity (97.73%), particularly with 36.6% females, support its utility across genders.[15] Bokade et al. found the Alvarado Score to be a fair predictor (53% prediction rate, AUC 0.528), while the AIR Score was poor (48%, AUC 0.482). At higher cut-offs (>7 for Alvarado, >8 for AIR), prediction rates improved to 92.2% and 95.6%, respectively. Our study's superior performance at standard cut-offs (e.g., 93.66% accuracy for Alvarado) suggests better generalizability, likely due to a larger sample (205 vs. 90) or consistent scoring. Their New Adult Appendicitis Score (87% prediction, AUC 0.868) outperformed both, indicating potential for alternative scoring systems, though not evaluated in our study.[16]

Memon et al. reported an Alvarado Score sensitivity of 13.36% but specificity of 92.31%, contrasting with our 92.55% and 97.73%. Their RIPASA Score's superior performance (94.01% sensitivity, 91.74% accuracy) suggests regional scoring systems may outperform standard ones in specific populations. Our study's high performance for both scores indicates robust applicability in our setting, possibly due to a higher prevalence (78.5% vs. 94.3%) or standardized protocols.[17] Naeem et al. found an Alvarado Score sensitivity of 83.3% and specificity of 41%, with an AUC of 0.628, lower than our 92.55%, 97.73%, and implied higher AUC. Their higher negative appendectomy rate (21% vs. our 0.5% false positives) suggests less stringent thresholds, whereas our study's precision minimized unnecessary surgeries.[18] Vaziri et al. reported the AIR Score as more sensitive (95%) and specific (74%) than the Alvarado Score (90% and 70%) in low-risk pediatric patients, but both were unreliable in high-risk cases. Our adult-focused study's superior performance (e.g., 97.73% specificity for both) highlights age-specific differences, as adult symptom reporting likely enhanced diagnostic accuracy.[19]

Zeb et al. found the RIPASA Score superior to AIR and Alvarado Scores, with the AIR Score showing better specificity than the Alvarado Score. Our study's high specificity for both scores (97.73%) contrasts with their findings, likely due to our adult cohort and high prevalence. Their negative appendectomy rate (8.3%)

was higher than our implied rate (~0.5%), suggesting our scores better minimized unnecessary surgeries.[20] Ghali et al. reported the AAS as more accurate (86.95% at ≥11) than the Alvarado Score. Our Alvarado Score's higher accuracy (93.66%) suggests it remains competitive, particularly in settings without AAS access. Their focus on reducing imaging aligns with our study's low false-positive rate, supporting clinical scoring to minimize radiological dependence.[21] Haak et al. found both scores limited in distinguishing complicated from uncomplicated appendicitis, with the Alvarado Score at ≥5 having 95% sensitivity but 8.99% specificity, and the AIR Score at ≥3 having 91.82% sensitivity and 18.53% specificity. Our study's focus on all appendicitis cases explains our higher specificity (97.73%) and accuracy (93.66% for Alvarado), as distinguishing complicated cases may reduce specificity. Their inclusion of imaging did not improve performance, suggesting clinical scores remain critical in resource-limited settings.[22] Kinesya et al.'s meta-analysis emphasized the Alvarado Score's utility in resource-limited settings, with high sensitivity for symptoms like right lower quadrant pain (83%) and specificity for elevated temperature (74%). Our study's high performance (e.g., 92.55% sensitivity) supports its use in similar contexts, particularly with a low false-positive rate (0.5%), reducing unnecessary interventions.[23]

The variability in diagnostic performance of the Alvarado and AIR Scores across studies highlights the impact of contextual factors such as disease prevalence, population demographics, and study design. Higher prevalence in our study enhanced positive predictive values but reduced negative predictive values, while adult cohorts and reliable symptom reporting improved sensitivity and specificity compared to pediatric studies. Standard cut-off thresholds optimized performance by balancing false positives and negatives, unlike higher or lower cut-offs in other studies that traded sensitivity for specificity. Prospective designs and larger sample sizes, as in our study, reduced bias and increased statistical power compared to retrospective or smaller studies. The Alvarado Score's simplicity suits resource-limited settings, while the AIR Score's reliance on laboratory markers benefits settings with robust diagnostic infrastructure, though our findings suggest the Alvarado Score slightly outperforms in sensitivity and accuracy.

Limitations of our study include the lack of subgroup analysis for complicated versus uncomplicated appendicitis, which may impact the performance of scoring systems. Future research should explore this distinction, as the appendicitis inflammatory response score may perform better in advanced cases. We did not compare imaging modalities, which could potentially enhance diagnostic accuracy when combined with clinical scoring systems.

## CONCLUSION

The study found that both the Alvarado and AIR scores offer strong diagnostic utility, with the Alvarado Score demonstrating slightly higher sensitivity and overall accuracy. These findings reflect variations influenced by factors such as population characteristics, disease prevalence, score thresholds, and methodological differences across studies. The Alvarado Score, due to its simplicity and reliability, remains a practical tool in emergency settings, particularly in low-resource environments. While the AIR Score showed marginally lower sensitivity, its diagnostic value remains significant, especially in cases suspected of advanced appendicitis.

## ETHICAL APPROVAL

Ethical approval of article was granted by the Ethical Committee of AIMTH, Sialkot;

## CONFLICT OF INTEREST

Authors declare no conflict of interest. FUNDING SOURCE: None

## AUTHOR'S CONTRIBUTIONS

ZK: Ideaology, data collection, analysis and drafted the manuscript
MQB: Supervision and critical review
MC: Assisted in literature review and data collection
MHH: Data analysis and interpretation
DM: Formatting and reference
FKR: Helping in data collection
All Authors: Approval of the final version of the manuscript to be published

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