Comparison of Clinical Scores for The Diagnosis of Acute Appendicitis in Children

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Abbreviations

AA - Acute appendicitis

PAS – Pediatric Appendicitis Score

Alvarado scor (MANTRELS) (Migration, Anorexia, Nausea, Tenderness, Rebound, Elevated temperature, Leukocytosis, Shift left)

ROC – Receiver Operating Characteristic

AUC – Area Under the Curve

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Abstract

Introduction: Acute appendicitis (AA) is the most common surgical abdominal condition and the leading cause of acute abdomen in the pediatric population. It requires rapid diagnosis, and many clinical scoring systems have been developed to aid in the diagnosis of AA. These scoring systems represent simple, non-invasive, and readily available diagnostic tools. The most commonly used scoring systems in children are the Alvarado score (MANTRELS) and the Pediatric Appendicitis Score – PAS (Samuel). The aim of this study is to determine and compare the diagnostic value of clinical scoring systems (Alvarado and PAS) in pediatric acute appendicitis.

Materials and Methods: A retrospective study was conducted for the period from January 1, 2023, to December 31, 2024. The study included 182 patients diagnosed with AA who underwent surgery and were hospitalized at the Pediatric Surgery Clinic of the Clinical Center of the University of Sarajevo (CCUS).

Results: The average age of patients with appendicitis was 11 years, corresponding mostly to school-age children, while 13.7% of the 182 patients were under 6 years of age. Based on histopathological findings, higher score values generally indicated more severe forms of appendicitis (gangrenous and perforated), while lower values were most often associated with phlegmonous appendicitis. The highest diagnostic value of the scores was observed in the time interval of 6–12 hours from the onset of symptoms. ROC analysis results showed that neither the Alvarado nor the PAS score had significant discriminative power in this sample. The average value of both Alvarado and PAS scores was 9. A statistically significant positive correlation was found (rho = 0.986; p = 0.000**) between Alvarado and PAS variables in patients with appendicitis. A statistically significant difference was also observed

Keywords

- Acute appendicitis
- Pediatric scoring systems
- Alvarado score
- PAS score

between the values of the Alvarado and PAS scores ($p = 0.046$, $p < 0.05$).

Conclusion: Although easy to apply, the Alvarado and PAS scores cannot be considered the sole and exclusive method for deciding on surgical treatment. The diagnosis of acute appendicitis can be improved by combining scoring systems with radiological diagnostics.

Introduction

Acute appendicitis represents the most frequent surgical emergency in the pediatric population.[1] It accounts for approximately 1–10% of children presenting with acute abdominal pain in emergency surgical settings.[2] In a small proportion of patients, the clinical features are straightforward and lead to an immediate diagnosis of acute appendicitis.[3] However, in most cases, establishing a diagnosis remains a significant challenge for surgeons.[4] Under such circumstances, surgical exploration may result in negative appendectomies, leading to the removal of a potentially functional organ.[5] Conversely, in delayed or overlooked cases, late diagnosis of acute appendicitis may result in serious complications such as perforation.[6] These complications contribute to increased morbidity and mortality, prolonged hospitalization, and impose both economic and social burdens on healthcare systems and communities. The differential diagnosis of acute appendicitis in children is broad, as many other conditions present with similar clinical manifestations, often leading to diagnostic delays.[7] To improve accuracy, several diagnostic modalities, including ultrasonography, computed tomography (CT), magnetic resonance imaging (MRI), and diagnostic laparoscopy, are currently employed.[8] In addition to imaging, a number of clinical scoring systems have been developed to facilitate timely diagnosis and reduce the incidence of unnecessary appendectomies.[9] These scoring tools typically incorporate the presence or absence of specific symptoms and signs, combined with laboratory markers such as leukocytosis.[10]

The Alvarado score[11] remains the most widely used system in clinical practice for diagnosing acute appendicitis. Although originally designed for adult patients, recent studies have also confirmed its applicability in pediatric populations.[12] In 2002, Samuel proposed a new pediatric-specific tool, the Pediatric Appendicitis Score (PAS), tailored to address the unique presentation in children.[13]

The primary aim of the present study was to compare the diagnostic performance of the Alvarado score and PAS in pediatric patients, in order to determine which scoring system provides greater reliability in identifying acute appendicitis.

Materials and Methods

This research was carried out as a retrospective study at the Clinic of Pediatric Surgery of the University Clinical Center Sarajevo. A total of 182 patients who underwent surgery between January 1, 2023, and December 31, 2024, were included and they were divided into following age groups: Group I from 0-5 years (the period of toddler and preschool age), Group II from 6-11 years (the school-age period), and Group III from 12-18 years (the puberty period). The study included patients aged 0 to 18 years who were hospitalized and underwent surgery at the Clinic for Pediatric Surgery for acute appendicitis.

Patients who were excluded from the study are the ones with congenital malformations of the gastrointestinal tract, diseases and inflammations of the ovaries in female children, abdominal trauma, and patients who had previously undergone an appendectomy.

The basis for the research was a questionnaire containing medical history (heteroanamnesis), and the Alvarado and PAS scores.

Statistical analysis

The statistical analysis of the data was done using the Excel program (Microsoft Office Excel 2017) and SPSS (Statistical Package for the Social Sciences) version 22.0. For categorical variables, the results are shown as absolute numbers and as the percentage frequency of individual categories. The Shapiro-Wilk test was used to assess the normality of the distribution of continuous variables. The significance of the difference for variables that followed a normal distribution was tested with the Student t-test, while the significance of the

difference for variables that did not follow a normal distribution was tested with the Mann-Whitney U test. For correlation between groups, Spearman's rho was used. The significance of the difference between variables between inidividual groups was determined by the Wilcoxon signed-rank test. The ROC curve (receiver operating characteristic) and the associated AUC (area under the curve) were used to determine the best cut-off values of a potential biomarker. Values of $p<0.05$ and $p<0.01$ were considered statistically significant.

Result

The study included 182 patients aged 0 to 18 years, who underwent a surgery because of the acute appendicitis at the Clinic of Pediatric Surgery of the University Clinical Center Sarajevo in the period from January 1, 2023, to December 31, 2024. Out of the total number of subjects with appendicitis, 119 (65.4%) were male, while 63 (34.6%) were female. The average age of the subjects with appendicitis was 11 (8 - 14.25) years. Of the total number of subjects with appendicitis, for 51 (28%), the time of onset of subjective complaints was within 6 hours of the initial examination by the surgeon; for 65 (35.7%) subjects, the first subjective complaints appeared between 6 and 12 hours from the initial examination; while for 66 (36.3%) subjects, the first subjective complaints appeared within 12 to 72 hours of the initial surgical examination. Out of the total number of subjects, 25 (13.7%) were less than 6 years old, while on the other hand, 157 (86.3%) were between 7 and 15 years old. Of the total number of subjects with appendicitis, 56 (30.8%) subjects had a gangrenous appendicitis on pathological findings, 16 (8.8%) had a perforated appendicitis, 86 (47.2%) subjects had a phlegmonous appendicitis, while 16 (8.8%) subjects had a chronic appendicitis on pathological findings, and 8 (4.4%) had a negative pathological finding.

The average value of the Alvarado score in subjects with appendicitis in the total population was 9 (8-9) **(Figure 1)**. The average value of the PAS score in subjects with appendicitis in the total population was 9 (8-9) **(Figure 2)**. A statistically significant positive correlation (rho=0.986; p=0.000**) was expressed in subjects with appendicitis between the variables Alvarado score and PAS **(Figure 3)**. A statistically significant difference was

found between the values of the Alvarado score and PAS, calculated by the Wilcoxon-signed rank test (p=0.046, p<0.05) **(Table 1).**

Sensitivity is 91.4%, specificity 0%, PPV 95.2% and NPV 0% for the Alvarado score in the diagnosis of appendicitis, while sensitivity is 92.5%, specificity 0%, PPV 95.3% and NPV 0% for the PAS score in the diagnosis of appendicitis in the total population of subjects **(Table 2).**

In subjects younger than 6 years, sensitivity is 100%, specificity 90.4%, PPV 15%, and NPV 0% for the Alvarado score, while in subjects aged 7 to 15 years, sensitivity is 90.4%, specificity 100%, PPV 85% and NPV 100% in the total population of subjects. In subjects younger than 6 years, sensitivity is 100%; specificity 91.7%, PPV 14.8%, NPV 0% for the PAS score, while in subjects aged 7 to 15 years, sensitivity is 90.4%, specificity 100%, PPV 85.2%, NPV 100% **(Table 3).**

In subjects whose subjective complaints began to appear within 6 hours of the first examination, sensitivity is 90%, specificity 88.6%, PPV 29.9%, NPV 6.7% for the Alvarado score, while for the PAS score sensitivity is 98%, specificity 90.5%, PPV 29.5%, NPV 7.1%. Also, in subjects whose subjective complaints began to appear between 6 and 12 hours from the initial examination, sensitivity is 92.3%, specificity 94.8%, PPV 35.9%, NPV 33.3% for the Alvarado score, while for the PAS score sensitivity is 92.3%, specificity 93.7%, PPV 33.5%, NPV 53.8%. In subjects whose subjective complaints began to appear between 12 and 72 hours from the initial examination, sensitivity is 86.4%, specificity 91.4%, PPV 51.8%, NPV 60% for the Alvarado score, while for the PAS score sensitivity is 89.3%, specificity 94.8%, PPV 34.9%, NPV 38.4% **(Table 4).** The AUC for the Alvarado score was 0.340 (95%CI 0.161 - 0.520), and it was higher compared to PAS (AUC 0.331, 95%CI 0.149 - 0.513), but did not show statistical significance for any of the variables (p=0.092, p=0.093, p<0.05) **(Figure 4, Table 5).**

Figure 1: Average value of the Alvarado score in subjects with acute appendicitis in the total population

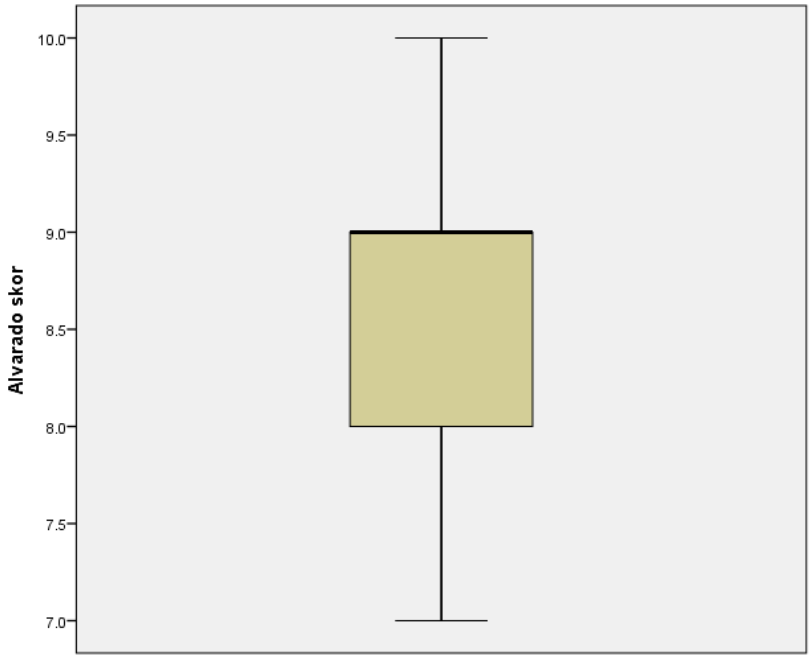


Figure 2: Average value of the PAS in subjects with appendicitis in the total population

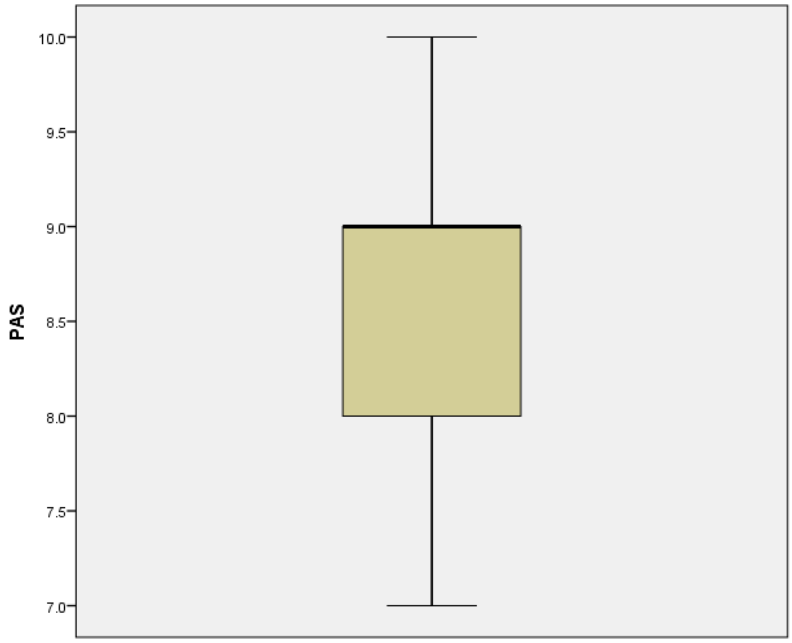
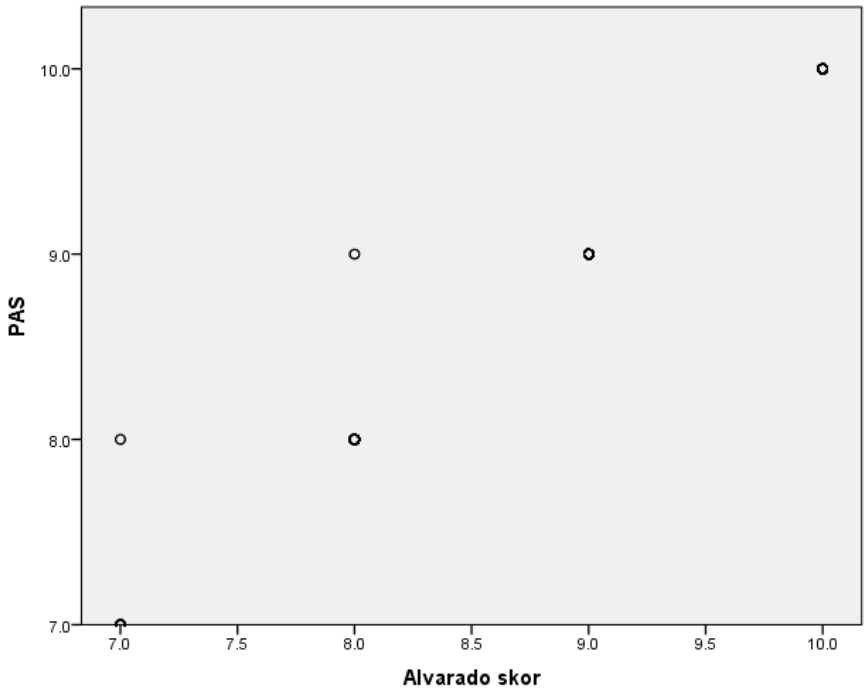


Figure 3: Correlation between the values of the Alvarado and PAS scores in subjects with app endicitis in the total population



Alvarado score	PAS	P
9 (8-9)	9 (8-9)	0.046*

PAS – pediatric appendicitis score, *p<0.05

Table 1: Comparison between Alvarado and PAS scores in subjects with acute appendicitis in the total population of subjects

	Alvarado	PAS*
Sensitivity %	91,4%	92.5%
Specificity %	0%	0%
PPV %	95.2%	95.3%
NPV %	0	0%

Table 2: Sensitivity, specificity, PPV and NPV of diagnostic scores in the diagnosis of appendicitis

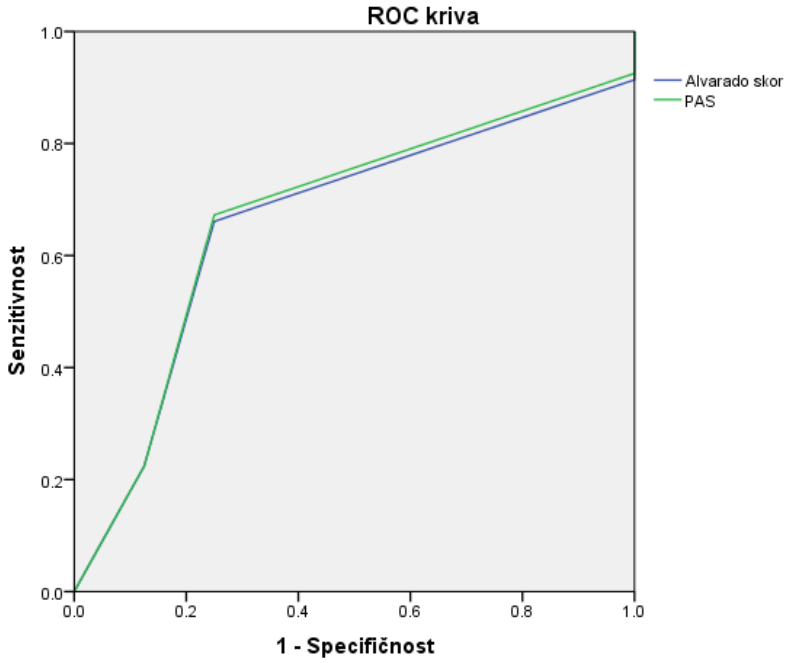
	Alvarado		PAS	
	0-6 years old	7-15 years old	0-6 years old	7-15 years old
Sensitivity %	100	90.4	100	90.4
Specificity %	90.4	100	91.7	100
PPV %	15	85	14.8	85.2
NPV %	0	100	0	100

Table 3: Sensitivity, specificity, PPV and NPV of diagnostic scores in relation to age

	Alvarado			PAS		
	<6h (n=12)	6-12h (n=17)	12-72h (n=71)	<6h (n=12)	6-12h (n=17)	12-72h (n=71)
Sensitivity % (95%CI)	90	92.3	86.4	98	92.3	89.3
Specificity % (95%CI)	88.6	94.8	91.4	90.5	93.7	94.8
PPV %	29.9	35.9	51.8	29.5	33.5	34.9
NPV %	6.7	33.3	60	7.1	53.8	38.4

Table 4: Sensitivity, specificity, PPV and NPV of diagnostic scores in relation to the onset of subjective complaints

Figure 4: ROC curve with Alvarado and PAS scores for subjects with acute appendicitis



	AUC	P	95% CI
Alvarado	0.340	0.092	0.161-0.520
PAS	0.331	0.093	0.149-0.513

Table 5: Presentation of ROC curve validation in subjects with appendicitis

Discussion

Acute appendicitis represents the most common surgical condition and it is one of the leading causes of acute abdomen in the pediatric age group.[14] Due to the complex clinical presentation, the focus is placed on timely, proper, and clear diagnosis using methods that facilitate the work of physicians with patients and reduce the overload of the tertiary level health care facilities. Radiological procedures like ultrasound, CT, and MRI are effective, but at the same time some of these methods are not cost-effective, and not economical, hence the search for tools that are available and economical – pediatric scores. The aim of using pediatric scores is to include and encompass clinical, laboratory, and increasingly ultrasonographic parameters, providing an objective, complete, and well-founded diagnosis of acute appendicitis.[15] There are large numbers of scores used both in the pediatric population and in adults to facilitate the diagnosis of appendicitis, prevent unnecessary appendectomies, and prevent complications of appendicitis. The scores used in this study are the Alvarado and PAS scores. Acute appendicitis occurs more frequently in children of preschool and school age.[16-17] In our study, the average age of subjects with appendicitis was 11 years, which corresponds more to school age, while 13.7% of the 182 subjects were under 6 years of age, indicating to us that appendicitis is more common in school age. This analysis shows that the highest diagnostic value was achieved in the interval of 6 to 12 hours from the onset of complaints. At this time, the sensitivity and specificity in both scores were the highest, suggesting that in this phase the symptoms reach sufficient prominence for precise clinical assessment, unlike the period between 12 and 72 hours where the sensitivity of both scores decreased. The results of the ROC analysis showed that neither the Alvarado nor the PAS score has significant discriminatory power in this sample – the AUC values were 0.340 for Alvarado and 0.331 for the PAS score. Compared to the study [18], where the AUC for Alvarado is 0.73 and for PAS 0.69, the results of this study are lower. This difference probably rises from the characteristics of the sample, the timeframe of symptom presentation, and limitations in the variability of diagnoses. Our results confirm the basic purpose of these scores, which is to assist in the early detection of appendicitis, which is particularly

important in children whose symptoms are often unclear and variable. The modern surgical approach strives to achieve a balance between the rate of negative appendectomies and the number of perforations recorded during operative treatment. Therefore, it is necessary to develop some prognostic criteria that will enable the timely identification of children at high risk for developing acute appendicitis.[15] Precisely for this reason, scores like PAS and Alvarado can significantly contribute to clinical assessment, although their limitations - such as the demonstrated low specificity - must be taken into account. Although some of the results of this research, such as low specificity and AUC values, deviate from the literature, it is important to emphasize that they do not diminish the value of the research - on the contrary, they further highlight it. The obtained data reflect the real challenges in the clinical diagnosis of acute appendicitis in children, especially in the context of emergency surgical evaluation where patients with a high clinical suspicion are often operated on . This very fact explains the high sensitivity and simultaneously low specificity of the scores in this sample. These results point to the need for careful and comprehensive clinical assessment and show that scores cannot be used alone, but as part of a broader diagnostic algorithm.

Limitations

This study has some limitations. First, this study was retrospective; and second, this study was a single-center study.

Conclusion

The Alvarado and PAS scores show high sensitivity in the diagnosis of acute appendicitis in children, making them useful clinical tools for the early recognition of the condition. These scores represent the making of protocol of clinical and physical findings, and they are valuable because the acute appendicitis can already be ruled out at primary health care level.

Ethical Consideration

Ethical approval for this study was obtained by the local institutional review board (Ethical Committee of the Clinical Center, University of Sarajevo, protocol code: 51-45-1-9063/25 date of approval: 10 March 2025). The requirement for informed consent was waived due to the retrospective nature of the study.

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Conflict of interests

There is no conflict of interest

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