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External Validation of a Prognostic Model for the Presence of Acute Appendicitis in Children

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Abstract

Background: Acute appendicitis is one of the most common and serious urgent pathologies in pediatric surgery. Rapid and accurate diagnosis of this condition is critically important to minimize the risk of complications such as appendix perforation, peritonitis, and sepsis. Despite the ongoing development of modern laboratory and instrumental diagnostic methods, identifying acute appendicitis in pediatric patients remains challenging. The present study aims to confirm the effectiveness and reliability of the developed prognostic model for predicting acute appendicitis in children and to compare its performance with previously established predictive methods.

Methods and Results: A new cohort of 101 pediatric patients with a confirmed diagnosis of acute appendicitis and 100 patients with functional gastrointestinal disorders were studied to assess the effectiveness of the developed logistic regression-based nomogram for predicting acute appendicitis in children. The predictive model incorporated clinical and laboratory parameters, including nausea, leukocyte and lymphocyte counts, appendix diameter on ultrasound, patient age, and vomiting. Using ROC curve analysis and confusion matrix assessment, the model's performance was compared to the Alvarado score and pediatric appendicitis score (PAS). The proposed model produced a minimal number of false-positive (14.8%) and false-negative results (9%). The ROC curve analysis confirmed superior diagnostic accuracy. The nomogram demonstrates the highest sensitivity (85.1%) and specificity (91.0%), indicating its superior ability to identify cases of appendicitis. The sensitivity and specificity of PAS were 80.2% and 88.0%, while AS showed 72.3% and 84.0%, respectively.

Conclusion: The developed predictive model is a reliable tool for diagnosing acute appendicitis in children, demonstrating higher accuracy than existing scoring systems. Its integration of clinical, laboratory, and ultrasound parameters enhances diagnostic precision and reduces the likelihood of unnecessary surgeries. Further external validation on larger populations is recommended to ensure its broad applicability in clinical practice.(**International Journal of Biomedicine. 2025;15(2):381-385.**)

Keywords: acute appendicitis • pediatric surgery • prognostic model • Alvarado score • pediatric appendicitis score

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Abbreviations

AA, acute appendicitis; **AS**, Alvarado score; **FGD**, functional gastrointestinal disorders; **NLI**, neutrophil-to-lymphocyte index; **PLI**, platelet-to-lymphocyte index; **PAS**, pediatric appendicitis score.

Introduction

Acute appendicitis (AA) is one of the most common and serious urgent pathologies in pediatric surgery. Rapid and accurate diagnosis of this condition is critically important to minimize the risk of complications such as appendix perforation, peritonitis, and sepsis.[1,2] Despite the ongoing development of modern laboratory and instrumental

diagnostic methods, identifying acute appendicitis in pediatric patients remains challenging. This is due to the peculiarities of children's psychological development and the various symptoms characteristic of acute appendicitis.[3-5]

Existing methods for predicting acute appendicitis in children, such as the Alvarado score and the pediatric appendicitis score (PAS), have been used in clinical practice for a long time. However, they exhibit insufficient sensitivity and specificity, which may limit their current applicability.[6-8] Therefore, there is a need to develop new, more accurate predictive tools for this condition.

The prognostic nomogram we previously developed for predicting acute appendicitis in children is based on several clinical and laboratory factors, including nausea, blood leukocyte and lymphocyte levels, appendix diameter on ultrasound, and patient age. This model was successfully validated on an internal dataset and demonstrated high accuracy, sensitivity, and specificity.

The present study aims to confirm the effectiveness and reliability of this prognostic model for predicting acute appendicitis in children and to compare its performance with previously established predictive methods.

Materials and Methods

A new cohort of 101 pediatric patients with a confirmed diagnosis of acute appendicitis and 100 patients with functional gastrointestinal disorders were studied to assess the effectiveness of the developed logistic regression-based nomogram for predicting acute appendicitis in children.

Patients received inpatient treatment in the Surgical Department at the Ulyanovsk Regional Children's Clinical Hospital from August 1, 2024, to December 31, 2024. All patients underwent the necessary diagnostic procedures in accordance with the Federal Clinical Guidelines "Acute Appendicitis in Children."[9] To analyze inflammatory manifestations, inflammatory response indices were calculated, including the neutrophil-to-lymphocyte index (NLI), platelet-to-lymphocyte index (PLI), and Garkavi index.[10] The ultrasound examination was performed for all patients upon admission to the hospital's emergency department using an expert-class ultrasound machine.

For predicting acute appendicitis, a previously developed logistic regression model was used, incorporating the following parameters: presence of nausea, blood leukocyte count, lymphocyte count, patient age, appendix diameter based on ultrasound findings, and presence of vomiting (patent application registration number – 2024122358) (Figure 1).

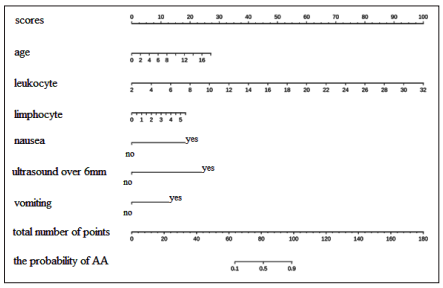

Fig. 1. *Nomogram for predicting acute appendicitis in children.*

The Alvarado score and pediatric appendicitis score (PAS) were also used to predict acute appendicitis. The parameters comprising Alvarado score included pain in the right iliac region, leukocytosis, a left shift in WBC count, nausea and/or vomiting, fever, migration of pain to the right iliac region, muscle resistance in the right iliac region, and tenderness on palpation in the right iliac region.[11] The parameters comprising PAS included pain in the right iliac region, pain with coughing, sneezing, or movement, leukocytosis, a left shift in WBC count, nausea and/or vomiting, anorexia, fever (>38°C), tenderness on palpation in the right iliac region, and muscle tension in the right iliac region.[12]

Statistical analysis was conducted using StatTech v. 4.5.0 (StatTech LLC, Russia). Baseline characteristics were summarized as frequencies and percentages. For descriptive analysis, results are presented as median (Me), first quartile (Q1), and third quartile (Q3). Mann-Whitney U test was used to compare differences between 2 independent groups. Sensitivity and specificity for the study tests were calculated. Receiver operating characteristic (ROC) curves were used to evaluate the performance of study models. The value of $P<0.05$ was considered significant.

Results

Tables 1–3 present the clinical and laboratory characteristics of study patients. Our study assessed the Alvarado score and PAS, as well as the developed nomogram, to predict acute appendicitis in children admitted to our hospital.

Table 1.

Demographic data of study patients.

Variable	Category	AA (n=101)	FGD (n=100)
Sex, n (%)	Girls	34 (33.7%)	54 (54%)
	Boys	67 (66.3%)	46 (46%)
Age group, n (%)	from 2 to 5 years	3 (3.0%)	30 (30%)
	from 6 to 9 years	24 (23.8%)	31 (31%)
	from 10 to 13 years	44 (43.5%)	22 (22%)
	from 14 to 17 years	30 (29.7%)	17 (17%)

Table 2.

Laboratory data of the patients as Me (Q1 – Q3).

Variable	AA (n=101)	FGD (n=100)	*P*-value
Leukocytes, 10^9/L	15.09 (11.78 – 18.33)	8.16 (6.35 – 11.12)	<0.001
Lymphocytes, 10^9/L	1.91 (1.43 – 2.44)	2.28 (1.42 – 2.86)	0.080
Neutrophils, 10^9/L	11.97 (8.07 – 14.88)	5.23 (3.27 – 7.98)	<0.001
Platelets, 10^9/L	307.00 (249.00 – 353.00)	275.50 (251.00 – 336.75)	0.135
NLI	6.57 (3.34 – 9.80)	2.24 (1.47 – 4.12)	<0.001
PLI	164.71 (115.73 – 215.13)	130.24 (98.24 – 193.99)	0.020

Table 3.

Pathomorphological findings in patients with acute appendicitis.

Variable	AA category	n	Percentage
Histological type	Catarrhal	8	7.9
	Phlegmonous	86	85.1
	Gangrenous	7	6.9

Figure 2 presents the confusion matrix, which visually demonstrates the number of correctly predicted outcomes by the model, as well as the number of false-positive and false-negative predictions. The model produces a minimal number of false-positive (14.8%) and false-negative results (9%).

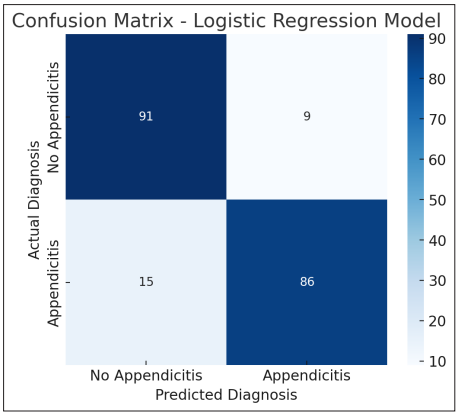

Fig. 2. *Confusion matrix for the logistic regression model.*

ROC curves were constructed to compare the effectiveness of the methods used to predict acute appendicitis in children (Figure 3). The nomogram demonstrates the highest sensitivity (85.1%) and specificity (91.0%), indicating its superior ability to identify cases of appendicitis. The sensitivity and specificity of PAS were 80.2% and 88.0%, while the Alvarado score showed 72.3% and 84.0%, respectively. Thus, the developed model is a reliable tool for assessing the risk of acute appendicitis in children and can be applied in clinical practice to support decision-making.

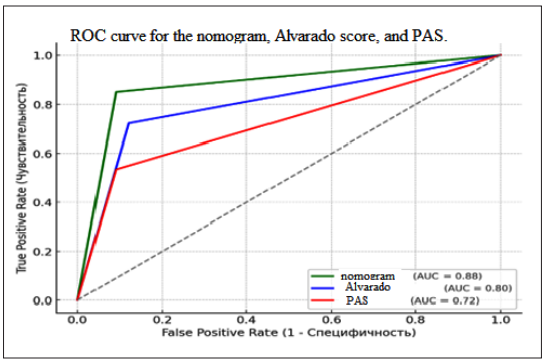

Fig. 3. *ROC curves for the study predictive models.*

Discussion

The diagnosis of acute appendicitis in children remains a significant challenge for surgeons. This is primarily because the clinical manifestations of the disease are often nonspecific, making accurate diagnosis difficult. All symptoms characteristic of appendicitis can also be observed in other conditions, complicating the timely decision-making process regarding the necessity of surgical intervention.[13,14]

Timely and accurate diagnosis, followed by surgical treatment, significantly increases the chances of a favorable outcome for the patient. Diagnostic errors may lead to delayed surgical treatment, which, in turn, increases the risk of severe complications. A large meta-analysis by Veeralakshmanan et al.[15] further emphasized the importance of early surgical intervention in acute appendicitis. On the other hand, excessive caution and unnecessary surgical procedures also have negative consequences, including surgical stress and potential risks associated with the operation, which is particularly important to consider when treating pediatric patients.[16-18]

Various methods for predicting acute appendicitis have been developed in response to this challenge, primarily in the form of scoring systems and indices. Some of these methods are widely used in clinical practice, while others have not gained significant adoption. For example, assessing inflammatory markers in blood is an accessible but not highly effective approach for predicting acute appendicitis. Most proposed biomarkers exhibit low sensitivity and specificity. Additionally, a major drawback of this method is its reliance solely on laboratory parameters without considering clinical and instrumental data.[19-22]

The Alvarado score and PAS are among the most commonly used scoring systems in clinical practice. A meta-analysis conducted by Bai et al.[23] reported that the specificity and sensitivity of the Alvarado score for diagnosing acute appendicitis in children were 76% and 71%, respectively, indicating moderate diagnostic accuracy. According to numerous studies, PAS is considered a convenient and reliable tool for predicting acute appendicitis in children.[24] However, both methods fail to incorporate ultrasound data, a key diagnostic criterion for acute appendicitis in pediatric patients.[25-27]

Thus, the task of early and accurate diagnosis of acute appendicitis in children requires special attention and further refinement of predictive methods to minimize both the risk of complications and the number of unnecessary surgical procedures.

The current study confirmed the high effectiveness of the developed model in predicting acute appendicitis in children, which is particularly important for improving differential diagnosis in emergency care settings. A key advantage of the proposed model is its integration of clinical and laboratory-instrumental parameters, allowing for a comprehensive approach to diagnosis. Comparison with other models, such as the Alvarado score, demonstrated that our model provides significantly better predictive accuracy.

However, our study has certain limitations. The primary limitation is the use of data from a single healthcare

institution, which may restrict the generalizability of the results to other hospitals. Additionally, further external validation on larger cohorts remains essential in enhancing the model's reliability. It is also important to emphasize that any predictive model serves only as an auxiliary tool and does not replace clinical reasoning and physician expertise. Despite its high accuracy, the clinician should make the final decision on patient management, considering all available clinical data.

Conclusion

The developed predictive model is a reliable tool for diagnosing acute appendicitis in children, demonstrating higher accuracy than existing scoring systems. Its integration of clinical, laboratory, and ultrasound parameters enhances diagnostic precision and reduces the likelihood of unnecessary surgeries. The implementation of this model in clinical practice will improve diagnostic accuracy, reduce the number of false-positive and false-negative diagnoses, and decrease the rate of unnecessary surgical interventions. Further external validation on larger populations is recommended to ensure its broad applicability in clinical practice.

Ethical Considerations

The study protocol was reviewed and approved by the Ethics Committee of the Ulyanovsk Regional Children's Clinical Hospital (Protocol No. 193, dated August 1, 2024). Written informed consent was obtained from the patient's legal representatives.

Competing Interests

The authors declare that they have no competing interests.

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