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Original Article

The Role of Alvarado and Pediatric Appendicitis Score in Acute Appendicitis in Children

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ABSTRACT

Aim: Acute appendicitis (AA) is the condition that most commonly requires a surgical procedure in children presenting to the emergency department with acute abdominal pain. Alvarado and Pediatric Appendicitis scores (PAS) are the most widely used scoring systems in the diagnosis of AA in children. This study aims to evaluate the effectiveness of Alvarado and PAS scores in the diagnosis of AA in children.

Materials and Methods: One hundred and two patients aged 3-17 years, who were admitted to the pediatric emergency department with acute abdominal pain and had a clinical suspicion of AA were included in this retrospective study. The demographic characteristics, laboratory and radiological findings, and Alvarado and PAS scores were obtained from the records of the patients, retrospectively. According to the results of pathology, n=48 patients for the AA group and n=54 patients for the non-AA group were identified. The AA and non-AA groups were compared in terms of PAS and Alvarado scores.

Results: The mean age of the 102 patients was 9.38±3.90 years, and 62 (60.85%) of them were male. The median PAS score was 7.79±1.2 and 5.52±1.34, and the median Alvarado score was 7.98±1.14 and 5.89±1.53 in the AA and N-AA groups, respectively ($p<0.001$; $p<0.001$). For the PAS, the cut-off score was >7 with a sensitivity of 66.7%, a specificity of 94.4%, a positive predictive value (PPV) of 91.4%, and a negative predictive value (NPV) of 76.1% ($p<0.001$). For the Alvarado score, the cut-off was also >7, with a sensitivity of 77.1%, a specificity of 85.2%, PPV of 82.2%, and NPV of 80.7% ($p<0.001$).

Conclusion: Although both PAS and Alvarado scores provide useful diagnostic information in patients suspected of AA, neither of them is enough to diagnose AA alone.

Keywords: Appendicitis, Alvarado score, children, PAS

Introduction

Acute appendicitis (AA) is the condition that most commonly requires a surgical procedure in children presenting to the emergency department with a sudden onset of abdominal pain (1).

Although the incidence is not known precisely, it is on the scale of 5.9/10,000 in the 0-9 years old age range, and 15.3/10,000 in the 10-19 years old age range in the United States of America (2). Also, in acute abdominal pain in children, AA was diagnosed for 7.4% in Australia (3). It has been shown that children with acute abdominal pain initially received other diagnoses frequently seen in children such as acute gastroenteritis, pneumonia, urinary tract infection, or mesenteric lymphadenitis (4). Perforation and related

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complications can be seen if the diagnosis cannot be made in time (4-7). In contrast to this, the frequency of negative appendectomy is reported to be at rates of 3.7-17% (7,8). Abdominal ultrasound (USG) is the most commonly used radiological method to help in making a correct diagnosis. Its sensitivity varies from 66.2% to 85% according to the practitioner's experience (8-10). The sensitivity of abdominal computed tomography (CT) is reported to be 95-97%, but there are risks such as radiation and post-contrast reactions (11,12). Therefore, scoring systems based on symptoms, physical examination, and laboratory findings have begun to be used. The Alvarado score, which was initially applied in adults, is also used in children. Subsequently, the Pediatric Appendicitis score (PAS) was developed by Samuel (13) in 2002. The Alvarado score and PAS have been reported to reduce the use of CT in the diagnosis of AA for patients between 3 and 16 years of age (14,15). This study aims to determine the PAS and Alvarado scores in patients admitted to the pediatric emergency department and considered to have AA, and to compare them in terms of applicability, safety, and specificity in the diagnosis of AA.

Materials and Methods

The retrospective observational study was conducted between November 2014 and November 2015, in the Clinic of Pediatric Emergency of Okmeydani Training and Research Hospital. The study included children aged 3-17 years who were admitted to the pediatric emergency department. Those patients who had a pain duration of less than 96 hours and were considered to have AA (abdominal sensitivity and defense or rebound tenderness positivity) after an examination by a pediatrician were included in this study. Pregnant patients, patients with chronic inflammatory bowel disease, cystic fibrosis, or sickle cell anemia, patients who had undergone a previous abdominal operation or abdominal tomography within the last two weeks and those who had received corticosteroids for more than two weeks, and immunosuppressed patients were not included in this study. The information cards of each patient were filled out before surgical consultation. Consent forms were obtained from the parents or the children. The age, gender, duration of pain, complaint (complaints of abdominal pain and duration, fever, nausea-vomiting, diarrhea, upper respiratory tract infection) physical examination findings (right lower quadrant sensitivity, defense, rebound tenderness, percussion/cough/right lower quadrant sensitivity with jumping) leucocyte count and neutrophil percentages, biochemistry, C-reactive protein, complete urine test, and PAS and Alvarado score parameters were marked on the forms of these patients.

According to previous studies, a neutrophil count ≥75% and a body temperature over 38 °C were accepted as fever. The parameters of PAS and Alvarado scores and their scoring systems are shown in Table I (16-18). All the patients underwent USG, and USG was considered to be positive in the presence of signs such as a fixed appendix, no compression, round transverse image appendix, thickening in the intestine wall, appendix inner diameter >6 mm, decreased mobility, irregular appearance in appendix, and peri-appendicular fluid appearance (9,10). All other USG findings were accepted as negative. A pediatric surgeon consulted with all the patients. The pediatric surgeon and the radiologist were not informed about the PAS and Alvarado scores. Other laboratory data and the radiological and pathological results of the patients were obtained from the system records. Those patients who were discharged

Table I. Alvarado and pediatric appendicitis scoring system (16-18)

Alvarado score		**Pediatric Appendicitis score**	
Feature	**Point value**	**Feature**	**Point value**
Migration of pain	1	Migration of pain	1
Anorexia	1	Anorexia	1
Nausea/vomiting	1	Nausea/vomiting	1
Signs RLQ tenderness	2	Signs RLQ tenderness	2
Rebound pain	1	Cough/hopping/percussion tenderness in the RLQ	2
Elevation of temperature (38 °C)	1	Elevation of temperature (38 °C)	1
Leukocytosis ≥10^9/L	2	Leukocytosis ≥10^9/L	1
Polymorphonuclear neutrophilia ≥75%	1	Polymorphonuclear neutrophilia ≥75%	1
Total	10	Total	10

Score <4 low, 5-6 intermediate, 7-10 high risky, Score <3 low, 4-6 intermediate, 7-10 high risky, RLQ: Right lower quadrant

without being operated on were called up and asked about whether they had undergone an operation within the previous two weeks. AA was diagnosed according to the observation of the pediatric surgeon during the operation and the pathology reports. Those patients who underwent surgery and were diagnosed with AA pathologically were accepted as the AA group, and those who did not undergo surgery or who underwent surgery but pathology results did not confirm AA were accepted as the non-AA group. The demographical characteristics, clinical, radiological and laboratory results, cut-off values of PAS and Alvarado scores, sensitivity and specificity values, positive predictive values (PPV), and negative predictive values (NPV) of the AA and non-AA groups were compared. Permission from the local ethics committee for this study was received from Okmeydani Training and Research Hospital Ethics Commitee (09/02/2016-416).

Statistical Analysis

The SPSS 22.0 (IBM SPSS, Turkey) was used in the analysis of the variables in this study. The conformity of the parameters to normal distribution was evaluated by Shapiro-Wilks test. In the comparison of quantitative data, Student's t-test was used for two groups of parameters with normal distribution and Mann-Whitney U test was used for two groups of parameters without normal distribution. In the comparison of qualitative data, chi-square test and Continuity (Yates) Correction was used. In the cut-off point identification, receiver operating characteristic (ROC) analysis was used, in the sensitivity and specificity calculations, diagnostic screening tests were used. The significance level was accepted as $p<0.05$. To compare qualitative parameters, Pearson chi-square test was used. For detecting cut-off points, ROC analysis was used, and for calculating sensitivity and specificity, diagnostic and screening tests were used. The DeLong method was used to compare two areas under the receiver operating characteristics curve (AUROC). The significance level was accepted as $p<0.05$.

Results

Of the 121 patients who were included in the study with the consideration of AA, 12 were excluded from the study due to a lack of information in the records and 5 because they could not be reached by phone. Of the remaining patients, 53 underwent surgery and one was diagnosed with Meckel's diverticulum and one with ovarian cyst; these 2 patients were excluded from the study. The mean age of the final 102 patients was 9.38±3.90 years (3-15.5 years), and 62 (60.8%) of them were male. Based on the pathological diagnoses, one patient had lymphoid hyperplasia, one patient had normal tissue, and one patient had carcinoid tumor. These 3 patients were excluded from the AA group and included in the non-AA group. The number of patients was 48 (47.1%) in the AA group and 54 (52.9%) in the non-AA group. There was no statistically significant difference between the two groups in terms of age, gender, and admission times. The most common finding (97.9%) of those patients in the AA group was sensitivity in the right lower quadrant. While there was a statistically significant difference between the AA group and the non-AA group in terms of sensitivity in the right lower quadrant, pain in the right lower quadrant with cough/percussion/hopping, migration of pain to the right lower quadrant, rebound tenderness, leukocytosis, or shift to the left, there was no statistically significant difference between the two groups in terms of anorexia, nausea-vomiting, or fever (Table II).

Among the patients in the AA group, the minimum PAS and Alvarado score was 5, the maximum score was 10 and all of patients who had scores of either 9 or 10 were in the AA group, while in the non-AA group, the minimum PAS and Alvarado score was 3, and the maximum score was 8.

For the PAS score, the cut-off value was >7, [95% confidence interval (CI), area under curve (AUC)=0.88±0.3] sensitivity was 66.7%, specificity was 94.4%, PPV was 91.4%, and the NPV was 76.1% ($p<0.001$) (Figure 1). For the Alvarado score, the cut-off value was >7, (95% CI, AUC was 0.87±0.03), sensitivity was 77.1%, specificity was 85.2%, PPV was 82.2%, and NPV was 80.7% ($p<0.001$) (Figure 1). By using the DeLong method, no statistically

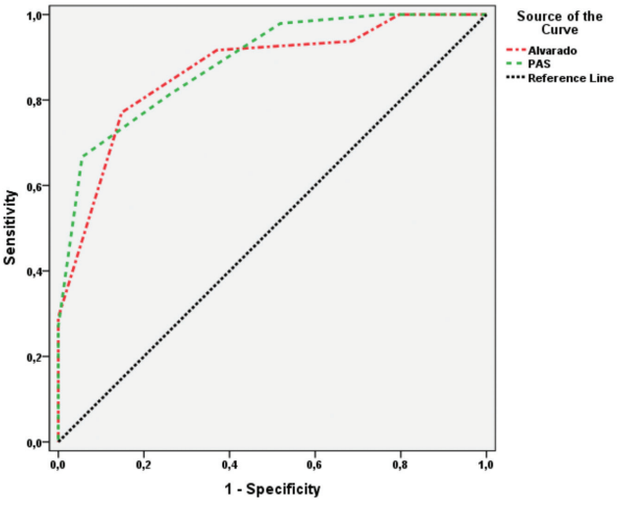

Figure 1. ROC curve of PAS and Alvarado score of patients
ROC: Receiver operating characteristic, PAS: Pediatric Appendicitis score

significant difference was found between the AUROC levels for Alvarado and PAS variables (p=0.530).

The USG findings were positive in 34 (70.8%) patients in the AA group, and 5 (9.3%) patients in the non-AA group. There was a significant difference in USG findings between the two groups (p<0.001) (Table II). For those patients in the AA group, PAS and Alvarado scores were in the intermediate or high risk group. There was statistically significant difference only for patients with Alvarado intermediate score in the comparison of USG results with the PAS and Alvarado scores of intermediate and high-risk group in patients in the AA group (p=0.047) (Table III). Abdominal CT was performed in 4 patients, and the results showed appendicitis in 2 of them, and the other patients underwent an operation after being evaluated by a surgeon.

Of the 51 patients who underwent surgery, negative appendectomy was seen in 3 (5.9%) patients. Of these patients, one had carcinoid tumor, one had lymphadenopathy and one had normal tissue (7-5); and the PAS and Alvarado scores of these patients were 8-8, 7-8, 7-5, respectively. Considering the pathological diagnoses of those patients

Table III. The comparison of ultrasound findings with the scores in acute appendicitis patients

	USG (-)	USG (+)	p
	n (%)	n (%)	
Alvarado			
5+6	20 (37.7)	7 (18.4)	**0.047***
≥7	33 (62.3)	31 (81.6)	
PAS			
5+6	25 (49.0)	11 (28.9)	**0.056**
≥7	26 (51.0)	27 (71.1)	

*: p<0.05, PAS: Pediatric appendicitis score, USG: Ultrasound

Table II. Features of group acute appendicitis and group non-acute appendicitis

	AA (n=48)	Non-AA (n=54)	Total (n=102)	p
	Med ± SD	Med ± SD	Med ± SD	
Age	10.09±3.79	8.75±3.91	9.38±3.90	[1]0.082
Duration (hour)$_{(med)}$	33.98±25.17 (24)	35.31±22.78 (24)	34.69±23.82 (24)	[2]0.386
Alvarado score$_{(med)}$	7.98±1.14 (8)	5.89±1.53 (6)	6.87±1.71 (7)	[2]<0.001*
PAS$_{(med)}$	7.79±1.2 (8)	5.52±1.34 (6)	6.59±1.71(7)	[2]<0.001*
C-reactive protein$_{(med)\ (mg/L)}$	54.51±76.98 (18.58)	31.12±62.52 (12.3)	42.13±70.33 (14.4)	[2]0.038*
Leukocytes count t (10^9/L)	16804.79±4822.02	14211.11±6825.95	15431.67±6079.71	[1]0.031*
Polymorphonuclear neutrophilia a (10^9/L)	12603.37±4220.14	10000.74±5802.04	11225.51±5258.99	[1]0.012*
	n (%)	n (%)	n (%)	
Gender				
Female	17 (35.4)	23 (42.6)	40 (39.2)	[3]0.459
Male	31 (64.6)	31 (57.4)	62 (60.8)	
Signs RLQ tenderness	47 (97.9)	42 (77.8)	89 (87.3)	[3]0.002*
Migration of pain	32 (66.7)	8 (14.8)	40 (39.2)	[3]<0.001*
Cough/hopping/percussion tenderness in the RLQ	36 (75)	18 (33.3)	54 (52.9)	[3]<0.001*
Rebound pain	35 (72.9)	13 (24.1)	48 (47.1)	[3]<0.001*
Elevation of temperature	11 (22.9)	20 (37)	31 (30.4)	[3]0.122
Anorexia	38 (79.2)	42 (77.8)	80 (78.4)	[3]0.865
Nausea/vomiting	36 (75)	35 (64.8)	71 (69.6)	[3]0.264
Leukocytosis ≥10 10^9/L	46 (95.8)	40 (74.1)	86 (84.3)	[3]0.003*
Polymorphonuclear neutrophilia ≥75%	44 (91.7)	36 (66.7)	80 (78.4)	[3]0.002*
USG	34 (70.8)	5 (9.3)	39 (38.2)	[3]<0.001*

[1]: Student t-test, [2]: Mann-Whitney U test, [3]: chi-square test ,*: p<0.05, PAS: Pediatric appendicitis score, RLQ: Right lower quadrant, AA: Acute appendicitis, Non-AA: non-acute appendicitis, SD: Standard deviation, USG: Ultrasound, Med: Median

in the AA group, 31 (64.6%) patients were diagnosed with phlegmonous appendicitis, 9 (18.7%) with gangrenous appendicitis, and 8 (16.7%) with perforated appendicitis. Of the patients in the non-AA group, 18 (35.3%) were diagnosed as acute gastroenteritis, 15 (29.4%) with constipation, 13 (25.5%) with mesenteric lymphadenomegaly, 2 (3.9%) with urinary tract infections, 1 (1.9%) with dysmenorrhea, 1 (1.9%) with Henoch-Schönlein purpura, and 1 (1.9%) with nephrolithiasis.

Discussion

Sensitivity in the right lower quadrant is the most common finding in appendicitis and is reported at a frequency of 78-100% in different series (1,15). Among other symptoms compatible with appendicitis, the shift of pain to the right lower quadrant is seen at a frequency of 33-69%, rebound pain at a frequency of 15-68%, and pain in the right lower quadrant with cough/percussion/jumping at a frequency of 64-83.2% (15,18-21). Leukocytosis frequency is 83-93% and an increase of the neutrophil ratio frequency is seen in 75-96% of cases with appendicitis (18-21). In our study, these ratios were found to be significantly higher than those of the non-AA group (p=0.003; p=0.02).

Samuel (13) determined the cut-off value to be 6 for the PAS. The cut-off value has been reported to be between 7-10, sensitivity to be between 61-86%, and specificity to be between 50-96% for the PAS in the different studies (15,19-22). The PPV values were between 50.7% and 90.1%, and NPV values were between 38% and 87.9% (15,19,20,23,24). Similarly, the cut-off value was >7, sensitivity was 66.7%, specificity was 94.4%, PPV was 91.4%, and NPV was 76.1% in our study. The cut-off values for the Alvarado score were similar to PAS. While the cut-off value was 7, the sensitivity was 68.5% to 89%, specificity was 59% to 81%, PPV was 54.9% to 93.1% and NPV was 46% to 85.3% (15,18-20,23,24). Similarly, in our study, the cut-off value was >7, while the sensitivity was 77.1%, specificity was 85.2%, PPV was 82.2%, and NPV was 80.7% for the Alvarado score. In our study, all of the patients had intermediate or high-risk scores for both PAS and Alvarado scores. On the other hand, when analyzed with ROC, there was no statistically significant difference in sensitivity, specificity, PPV and NPV between the PAS and Alvarado scores.

In the diagnosis of AA, the sensitivity of abdominal USG varies according to the experience of the practitioner, the visualization of the appendix, the gender of the patient, the patient's body weight, and the visualization of the perforated appendicitis. The abdominal USG sensitivity for AA diagnosis varies between 53% and 88.2% and specificity between 84% and 93% in different series (10,16,23,25-28). On the other hand, the false positive USG frequency is seen to be between 5% and 30% (23,29-31). It has been suggested that the USG positivity and diagnosis rate increases as the duration of pain increases in these patients (27). Although Alvarado and PAS recommends radiological methods, especially USG, for those patients with intermediate scores, some other centers also recommend using radiological methods for those patients with lower scores (28,29). In our study, abdominal USG was found to be positive in 70.8% of those patients in the AA group, and in 9.3% of those patients in the N-AA group. Sincavage et al. (25) showed intermediate risk AS (4-6), US was positive for appendicitis in 21%. Our study had similar results.

Perforation can be a fatal complication in AA in children. Perforation frequency between 7.5% and 30% has been reported in various studies (16,29,32,33). According to the results of the pathologic examinations, the simple or phlegmonous appendicitis is reported at a frequency of 25% to 57.1%, gangrenous or suppurative appendicitis at a frequency of 34% to 45%, and perforated appendicitis at a frequency of 12% to 21% (4,32,33). In our study, 31 (64.6%) patients were diagnosed with simple appendicitis, 9 (18.7%) patients with gangrenous appendicitis, and 8 (16.7%) patients with perforated appendicitis.

In children, negative appendectomy rates are reported between 3.7% and 13% in different series (7,8,16,32,33). While it is expected that the rate of negative appendectomy in high-score patients is low, Zúñiga et al. (33) found negative appendectomy to be at a rate of 4.95% in those with a PAS score above eight. In our study, all patients with a score of more than 8 were in the AA group. The pathologic diagnoses were normal tissue, fecaliths, lymphoid hyperplasia, pinworm, granuloma, Meckel's diverticulum, granuloma, fibrose obliteration, and carcinoid tumor (34,35). Three (5.9%) patients had a negative appendectomy. The scores of these 3 patients were between 5 and 8 and they were diagnosed as normal tissue, lymphoid hyperplasia and carcinoid tumor pathologically. The patient who was pathologically diagnosed with carcinoid tumor had an Alvarado score of 8, a PAS score of 8, leukocytosis, and shift to the left, but no USG findings. If positive USG findings, leukocytosis and neutrophyl count >75% are not observed together in a patient, close follow-up and radiologic re-evaluation should be considered.

Study Limitations

Firstly, this study was conducted with a limited number of patients. Secondly, the patients were not all examined

by the same physician. Finally, the fact that the patients did not apply within the same period following the onset of the complaint is thought to affect the clinical staging, laboratory findings, and radiological findings.

Conclusion

AA is a condition that is still hard to diagnose in children presenting with acute abdominal pain in the emergency department. Although both Alvarado and PAS scores provide useful information in patients suspected of having AA in the pediatric emergency department, neither of them is enough to diagnose AA alone. The possibility of AA is high in children with a PAS and Alvarado score of 5 or more in the presence of radiological findings. There is a need for new parameters in the scoring system.

Ethics

Ethics Committee Approval: Permission from the local ethics committee for this study was received from Okmeydani Training and Research Hospital Ethics Commitee (09/02/2016-416).

Informed Consent: Consent forms were obtained from the parents or the children.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: Y.T., A.K., E.D., S.K., A.A.G., C.A., Ö.E.G.T., A.Kan., O.Ö., Design: Y.T., A.K., E.D., S.K., A.A.G., C.A., Ö.E.G.T., A.Kan., O.Ö., Data Collection or Processing: A.K., S.K., A.A.G., Ö.E.G.T., A.Kan., Analysis or Interpretation: A.K., Y.T., C.A., A.Kan., O.Ö., Literature Search: S.K., Ö.E.G.T., Writing: Y.T., E.D.

Conflict of Interest: None of the authors had conflict of interest.

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