Medical Science

25(111), May, 2021

Validity of pediatric appendicitis score in predicting disease severity in pediatric acute appendicitis

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To Cite:
Hiep NT, Minh NC. Validity of pediatric appendicitis score in predicting disease severity in pediatric acute appendicitis. *Medical Science*, 2021, 25(111), 1213-1217

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Peer-Review History
Received: 09 April 2021
Reviewed & Revised: 10/April/2021 to 15/May/2021
Accepted: 15 May 2021
Published: May 2021

Peer-review Method
External peer-review was done through double-blind method.

ABSTRACT

Objective: This study aims to evaluate the validity of Pediatric Appendicitis Score in predicting disease severity of acute pediatric appendicitis. *Methods:* We prospectively evaluated 120 children who underwent surgery for acute appendicitis. We enrolled them into two groups: uncomplicated appendicitis (n = 86) or complicated appendicitis (n = 34). We compared the age, blood test results, body temperature, hospital stay, number of complications, and pediatric appendicitis score between the two groups. We evaluated the diagnostic value (specificity, sensitivity, negative predictive and, positive predictive value), and value of the PAS to distinguish complicated from uncomplicated appendicitis. A receiver operating characteristic curve (ROC) was produced to find the appropriate cut-off value to distinguish complicated from uncomplicated appendicitis. To explore the severity of the disease, we divided the pediatric patients into two groups according to that cut-off value. *Results:* There were significant differences in the PAS score between uncomplicated and complicated appendicitis (5.7 versus 7.8). The ROC showed a PAS cut-off value of 8. A PAS ≥ 8 had a sensitivity of 73.1%, a specificity of 89.2%, a positive predictive value of 91.4%, and a negative predictive value of 68.5%. A PAS ≥ 8 was correlated with significantly more extended hospital stay and more complications than a PAS < 8. *Conclusions:* The pediatric appendicitis score (PAS) may be correlated with disease severity in acute pediatric appendicitis.

Keywords: acute appendicitis; pediatric appendicitis score; complication

1. INTRODUCTION

Acute appendicitis is the most common surgical emergency in children (Masoomi et al., 2014). Despite its high incidence, it is sometimes difficult to make an accurate diagnosis of appendicitis (Sivit et al., 2001; Mundada et al. 2020). The effectiveness of antibiotics has been reported for the treatment of uncomplicated appendicitis (UA) in children (Gorter et al., 2017; Huang et al., 2017). To select the appropriate therapy, it is important to accurately distinguish between UA and complicated appendicitis (CA).

The Pediatric Appendicitis Score (PAS) is used to diagnose acute appendicitis in children. The PAS is composed of simple items consisting of clinical symptoms, physical findings, and blood test findings. The PAS can be easily evaluated, so it has been used widely. To evaluate whether the PAS could be useful as a prognostic indicator in appendicitis, we investigated the relationships between the PAS and pathological progression and disease severity in cases of acute appendicitis in children.

2. MATERIALS AND METHODS

Study patients

We prospectively evaluated children who underwent surgery for acute appendicitis in our hospital during April 2017 and September 2019. The exclusion criteria were as follows: patients aged 16 years or older and those who underwent interval appendectomy were excluded. On the basis of pathological and intraoperative findings, we divided the patients into two groups according to the diagnosis of UA or CA. Complicated appendicitis was defined as gangrenous appendicitis or perforated appendicitis diagnosed pathologically, or abscess formation found intraoperatively. Uncomplicated appendicitis was defined as appendicitis other than that previously mentioned (Bhangu et al., 2015).

Data collection

We compared the influence of age, body temperature, WBC count, hospitalization period, and the PAS between the two groups. We calculated the PAS based on the following parameters: (i) cough / percussion / hopping tenderness: 2 points, (ii) anorexia: 1 point, (iii) pyrexia: body temperature ≥38 °C: 1 point, (iv) nausea / emesis: 1 point, (5) tenderness in the right lower quadrant: 2 points, (vi) leukocytosis: leukocyte count ≥ 10 000/μL: 1 point, (vii) polymorphonuclear neutrophilia: neutrophil ≥ 75%: 1 point, and (viii) migration of pain: 1 point (Lovell, 2019).

Statistical analysis

We calculated the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of the PAS for diagnosing CA. A receiver operating characteristic (ROC) curve was also constructed to evaluate the optimal cut-off value of the PAS for diagnosing CA. The best cut-off value was based on the calculation of the Youden index (Youden, 1950). Then, to assess the severity of acute appendicitis, we divided the patients into two groups according to the cut-off value of the PAS mentioned above and compared the influence of age, body temperature, WBC, CRP level, hospitalization period between those two groups. Between-group differences were compared using Student's *t*-test (age and body temperature), Mann–Whitney's *U*-test (PAS, WBC, CRP level, and hospitalization period), or Fisher's exact test (complications). The ROC curve was constructed using IBM SPSS Statistics (SPSS Inc., Chicago, IL). Statistical significance was set at $P < 0.05$.

3. RESULTS

A total 120 patients were enrolled in this study. Eighty-six patients (71.7%) were diagnosed with UA, and 34 patients (28.3%) were diagnosed with CA. Of the CA patients, 24 were diagnosed with gangrenous appendicitis, and 10 were diagnosed with perforated appendicitis. Table 1 shows the patients' characteristics. The mean (±standard deviation) PAS was 7.2 ± 1.7. There were statistically significant differences in the body temperature (37.4 versus 37.9 °C, $P = 0.0040$), WBC (13,631 versus 17,594/μL, $P < 0.001$), hospital stay (4.4 versus 6.4 days, $P = 0.0003$), and mean PAS (5.7 versus 7.8 points, $P < 0.001$) between UA and CA.

Table 1 Characteristics of the patients

Variables	SA (n = 86)	CA (n = 34)	P-value
Age (years)	8.9 (2.8)	9.9 (3.5)	0.104
Body temperature (°C)	37.4 (0.83)	37.9 (0.87)	0.004
WBC (/μL)	13,631 (3,561)	17,594 (5,291)	< 0.001
Hospital stay (days)	4.4 (2.1)	6.4 (3.7)	0.0003
PAS	5.7 (1.3)	7.8 (1.1)	< 0.001

CA, complicated appendicitis; PAS, Pediatric Appendicitis Score; UA, uncomplicated appendicitis; WBC, white blood cell count. Data are presented as mean (standard deviation) or *n* (%), unless otherwise indicated. Pediatric Appendicitis Score distribution of the patients with UAor CA. The median PAS of patients with UA was 6 points, and that of patients with CA was 8 points.

The median PAS of patients with UA was 6 points, and that of patients with CA was 8 points. Table 2 shows the sensitivity, specificity, PPV, and NPV of the PAS for diagnosing CA. A PAS ≥ 8 had a sensitivity of 73.1%, specificity of 89.2%, PPV of 91.4%, and NPV of 68.5%. The ROC curve of the PAS for diagnosing CA is shown in Figure 1. The area under the ROC curve of the PAS was 0.89, and the Youden index cut-off value for the PAS was 8. Table 3 shows the patients' characteristics according to a PAS < 8 and ≥8 points. Patients with ≥8 points had a significantly higher body temperature (37.3 versus 38.2 °C, $P < 0.001$), higher WBC (14,504 versus 17,691/μL, $P = 0.0007$), longer hospitalization (6.4 versus 4.2 days, $P < 0.001$) than those with a PAS < 8.

Table 2 Sensitivity, specificity, PPV, and NPV of the PAS for diagnosing CA

PAS	Sensitivity	Specificity	PPV	NPV
1	1.00	0.00	0.61	0.00
2	1.00	0.00	0.61	0.00
3	1.00	0.00	0.61	0.00
4	1.00	0.00	0.071	1.00
5	1.00	0.00	0.21	1.00
6	0.93	0.32	0.68	0.75
7	0.86	0.71	0.83	0.77
8	0.73	0.89	0.91	0.68
9	0.32	1.00	1.00	0.48
10	0.023	1.00	1.00	0.39

CA, complicated appendicitis; NPV, negative predictive value; PAS, Pediatric Appendicitis Score; PPV, positive predictive value.

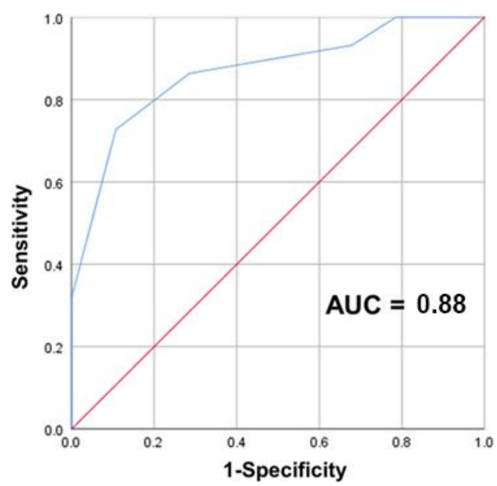

Figure 1 Receiver operating characteristic curve of PAS for diagnosing CA. The area under the ROC curve (AUC) of the PAS was 0.88.

Table 3 Characteristics according to the PAS

	PAS < 8 (n = 57)	PAS ≥ 8 (n = 63)	P-value
Age (years)	9.9 (2.9)	9.8 (3.5)	0.1116
Body temperature (°C)	37.3 (0.75)	38.2 (0.79)	<0.001
WBC (/μL)	14,504 (4,069)	17,691 (5,519)	0.0007
Hospital stay (days)	4.2 (1.9)	6.4 (2.9)	<0.001

PAS, Pediatric Appendicitis Score; WBC, white blood cell count. Data are presented as mean (standard deviation) or n (%), unless otherwise indicated.

4. DISCUSSION

The effectiveness of antibiotics has been reported for the treatment of UA in children (Gorter et al., 2017; Huang et al., 2017). A meta-analysis showed that initial antibiotic treatment of UA was comparable with appendectomy, with a high rate of success, and treatment with antibiotics alone was not associated with increased complications (Huang et al., 2017). Thus, accurate distinction between UA and CA is important, as antibiotic treatment for UA could be an option for initial treatment. Several attempts have been made in different ways to predict the severity of appendicitis. Kaneko and Tsuda (2004) reported that ultrasonography in children could not only visualize all inflamed appendices but could also predict the severity of the disease. Hoecker and Billman (2005) also reported that histopathological progression of appendicitis can be estimated by computed tomography (CT). However, there are some problems in that ultrasonography may depend on the skill of the operator, and CT has a risk of radiation exposure (Brenner et al., 2001).

The PAS was firstly reported by Samuel (2002) for diagnosing acute appendicitis in children. The PAS is mainly scored based on clinical symptoms, physical findings, and differential WBC. Because of its convenience, this score has been used widely as a diagnostic tool for acute appendicitis in children. A score ≥ 6 was reported to be compatible with the diagnosis of appendicitis (Samuel, 2002). However, there has been no report on how many points of the PAS are likely to indicate CA.

We found that there was a statistically significant difference in the PAS between UA and CA. Thus, the PAS may be correlated with histopathological progression. In addition, the Youden index cut-off value of the PAS for diagnosing CA was 8. At 8 points, the AUC was 0.88. This value was recognized as an accurate value for diagnosing CA. The PPV of a PAS ≥ 8 for diagnosing CA was also 91%, which was reasonable for diagnostic use. Patients with 8 points showed a significantly longer hospitalization and more complications than those with <8 points, suggesting that the PAS is correlated with the severity of appendicitis. Adibe *et al., (2011)* also reported that, as the PAS increased, the more pathologically advanced the disease was and the longer the hospital stay.
As a point of note regarding the PAS, the reported scores are some what different. Indeed, the mean PAS in our study was 7.2 ± 1.7 (mean ± standard deviation), but in other reports, it varied: Samuel, (2002) 9.1 ± 0.1; Goldman *et al.,* (2008) 7.0 ± 2.2; and Salö *et al.,* (2014) mean 6.4.

We thought that these differences may be due to difficulty in evaluating the PAS during physical examinations. Salö *et al., (2014)* reported that the mean PAS was lower in younger children (<4 years) than in older patients (≥4 years) because it was difficult to perform physical examinations accurately and to listen to young children describe their medical history. When using the PAS in young people, it is necessary to pay close attention when evaluating the severity of the disease.

This study has several limitations. First, it was a retrospective study with no control group. Second, the number of cases was small, which may have weakened the significance of our findings. To resolve these problems, a prospective randomized controlled trial should be performed in the future with a larger number of subjects. Third, Huang et al., (2017) defined CA as perforation and / or gangrene due to appendicitis or development of an appendiceal mass or abscess. The definition of UA and CA in this study was slightly different from that in Huang et al.'s study. It might not be possible to determine the treatment policy of acute appendicitis based on only our results.

5. CONCLUSION

We found that there was a statistically significant difference in the PAS between UA and CA. The PAS may therefore correlate with histopathological progression. A PAS ≥ 8 had a PPV of 91.1% for diagnosing CA in this study. Patients with ≥8 points showed significantly longer hospital stay and more complications than those with <8 points, suggesting that the PAS also correlated with the severity of appendicitis. The PAS could be considered not only as a diagnostic tool but also as a judgment tool for deciding the treatment plan.

Author Contributions

Both authors contributed equally to this work.

Funding

This study has not received any external funding.

Conflict of Interest

The authors declare that there are no conflicts of interests.

Ethical approval

The study was approved by the Medical Ethics Committee of Pham Ngoc Thach University of Medicine (ethical approval code: 017/PUM).

Data and materials availability

All data associated with this study are present in the paper.

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