

## Pediatric Appendicitis Score for Identifying Acute Appendicitis in Children Presenting With Acute Abdominal Pain to the Emergency Department

SYED MAAZ SALAHUDDIN,<sup>1</sup> OMAIR AYAZ,<sup>1</sup> MEHTAB JAFFER,<sup>1</sup> RUBABA NAEEM,<sup>1</sup> SHIYAM SUNDAR TIKMANI,<sup>2</sup> ASAD IMIAN<sup>1</sup>

From <sup>1</sup>Departments of Emergency Medicine, and <sup>2</sup>Community Health Sciences, Aga Khan University, Karachi, Pakistan.

Correspondence to: Dr Syed Maaz Salahuddin, Instructor, Department of Emergency Medicine, Aga Khan University, Karachi, Pakistan.  
maaz.salahuddin@hotmail.com  
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**Objective:** To determine the diagnostic accuracy of Pediatric Appendicitis Score (PAS) in predicting appendicitis in children presenting with acute abdominal pain to the Emergency Department (ED) of a private hospital in Pakistan. **Methods:** This validation study was through retrospective chart review of children between 4-18 years of age with clinical suspicion of acute appendicitis, presenting to the pediatric ED. Diagnostic accuracy was determined using sensitivity, specificity, predictive values, and area under the curve (AUC). **Results:** 104 children (76% boys) with mean (SD) age of 10.9 (3.5) years met the eligibility criteria. 91% ( $n=95$ ) patients had moderate to high PAS (score  $\geq 4$ ), and 95% ( $n=99$ ) had biopsy-proven appendicitis. The likelihood ratio calculated for low, equivocal and high-risk PAS was 0.10, 2.17 and 2.53, respectively. An equivocal PAS (score 4-6) showed a sensitivity of 96.8%, specificity of 80%, positive predictive value of 98.9% and AUC of 0.84 for predicting acute appendicitis. **Conclusion:** PAS showed good diagnostic accuracy in predicting acute appendicitis in children presenting to the ED.

**Keywords:** Diagnosis, Management, Perforation, Right quadrant pain, Surgery.

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Appendicitis is one of the leading causes of abdominal pain in the pediatric population, and it usually requires immediate surgical intervention [1]. Timely diagnosis of a child with appendicitis is extremely important [2], as there is a risk of perforation in 12.5-30% of cases [3-5]. There is a high chance of misdiagnosis and it has been reported that approximately 28-57% of children of school going age are misdiagnosed [4].

To limit exposure to ionizing radiations during computerized tomography (CT) [4], and to overcome the subjective nature of USG [6], in children, different scoring systems have been used for the diagnosis of appendicitis. Two of the most common scoring systems are the Alvarado scoring system [3] and the Pediatric appendicitis score (PAS) [7]. Both scoring systems assign point values to data collected from patient history, physical examination and laboratory tests, and determine cut-offs to predict presence of appendicitis. There is conflicting evidence in the literature regarding the utility of these two scores in diagnosing acute appendicitis in children [8,9].

The scores may be particularly beneficial for developing countries, due to the limited access to diagnostic modalities in many health centers. Thus, our primary objective was to validate PAS in predicting appendicitis in

children presenting with acute abdominal pain to the Emergency Department (ED) of a private hospital, and also to study the association of PAS with the gold standard (histopathology), and with ultrasound imaging.

### METHODS

This was a retrospective chart review conducted by accessing records of children aged 4 to 18 years, brought to the pediatric ED from January 1, 2010 to December 31, 2012.

The ED of Aga Khan University Hospital (AKUH), a large urban tertiary care hospital, is a 62-bed facility receiving an average of 170 patients daily (around 1/3rd <18 years old). Pediatric patients receive initial management in the ED and those who are clinically stable get discharged, while remaining are then transferred to the pediatric inpatient wards, Pediatric intensive care unit (PICU) or the special care unit (SCU) for further management.

Ethical approval for this study was obtained from Ethics Review Committee of Aga Khan University Hospital, due to the nature of the study (retrospective chart review), consent was not deemed necessary.

We included children of either gender between 4-18 years of age who presented with acute abdominal pain (up

to 24 hours) of varying severity to the pediatric ED. Patients were excluded if they had ectopic pregnancy, lymphoproliferative disorder, abdominal trauma, or were referred for pre-diagnosed appendicitis.

Data were collected via review of files and the Patient Care Inquiry software, and included demographics, clinical signs and symptoms, laboratory and histopathology results. The data retrieved had initially been recorded in the patients' clinical file by a pediatric resident, senior medical officer and/or faculty. The initial clinical findings had been reviewed by the pediatric surgery team. We calculated the PAS of patients diagnosed clinically with acute appendicitis using the information provided at initial clinical presentation. Appendicitis was defined as appendectomy with positive histopathology results (gold standard). We then sought associations between the PAS score and histopathology results of those patients.

Sample size calculation was based on surveillance showing 19% of children who came to the hospital with complaint of acute abdominal pain would have acute appendicitis [10]. Assuming that PAS has a sensitivity of 92% and specificity of 88% for acute appendicitis [9,10], the estimated sample size calculated for this study was 104 children (with 95% confidence) at  $\alpha=5\%$  and power of 0.8.

**Statistical analysis:** Data were entered and analyzed using SPSS v21. PAS was calculated as a continuous variable (0-10) and then categorized as low (<4), equivocal (4-6) and high risk (>6) for acute appendicitis. Frequencies and percentages were derived for categorical variables, and mean and standard deviations for normally distributed continuous variables. Predictive values and area under the curve (AUC) were calculated to determine the diagnostic performance of PAS. Associations between the PAS and clinical outcomes were made, including comparison between PAS and ultrasound, CT scan and histopathology results.

## RESULTS

For the study period, data on a total of 104 patients (76% boys) with clinical suspicion of acute appendicitis was

**Table I Clinical Characteristics of Children With Suspected Acute Appendicitis (N=104)**

Characteristics	Value
Age <sup>a</sup>	10.9 (3.5)
Male	79 (76)
Right lower abdomen pain	79 (76)
Migration of pain	68 (65.4)
Anorexia	40 (38.5)
Nausea/vomiting	89 (85.6)
Right lower quadrant tenderness	95 (91.3)
Coughing/hopping/percussion pain	23 (22.1)
Fever	48 (46.2)
Leukocytosis	85 (81.7)
Left shift on WBC differential	91 (87.5)

Values in no. (%) or <sup>a</sup>mean (SD). WBC-white blood cells.

analyzed. The mean (SD) age of the patients enrolled was 10.9 (3.5) years. The clinical parameters for the PAS are given in **Table I**. Although, 76% ( $n=79$ ) of patients presented with right lower abdominal pain, 23% had umbilical pain. The mean (SD) PAS was 6.3 (1.6), with the maximum score being 10 in one child. Low risk probability PAS (score <4) was seen in 8.7% children; however, 43% had equivocal PAS (score 4-6) and 49% had high-risk PAS (score >6) probability. The likelihood ratio calculated for low, equivocal and high risk PAS was 0.10, 2.17 and 2.53, respectively (**Table I**).

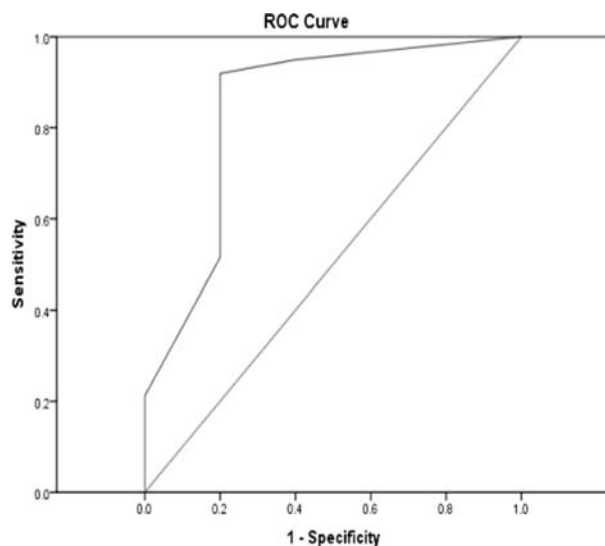
Majority of patients underwent imaging (88.5%), and ultrasound abdomen was the preferred imaging modality (64.4%) in these children. However, four patients (3.8%), in whom ultrasound abdomen was not suggestive of appendicitis, had to go through focused (unenhanced) abdominal CT scan, before surgery was opted.

Surgical intervention was performed by the pediatric surgery team in all 104 patient, of which, 99 patients (95.2%) had biopsy proven appendicitis; biopsy being positive in 6 (66.6%), 43 (97.7%) and 50 (98%) children with low-risk, equivocal and high-risk PAS, respectively.

**Table II Diagnostic Performance of Pediatric Appendicitis Score (PAS) at Various Cutoff Points**

	PAS <4	PAS 4-6	PAS >6
Sensitivity	93.94 (87.27-97.74)	96.81 (90.96-99.34)	74.75 (65.02-82.94)
Specificity	60 (14.66-94.73)	80 (28.36-99.49)	80 (28.36-99.49)
Positive predictive value	97.89 (94.07-99.27)	98.91 (94.03-99.81)	98.67 (92.74-99.77)
Negative predictive value	33.3 (14.82-58.96)	57.14 (28.72-81.52)	13.79 (8.42-21.78)
Accuracy	92.3 (85.4-96.62)	95.96 (89.98-98.89)	75 (65.55-82.97)

Values in point estimate (95% CI).



**Fig. 1** Receiver operating characteristic curve for pediatric appendicitis score (PAS).

The PAS was compared for low, equivocal and high-risk and for each probability, sensitivity, specificity, PPV and NPV along with accuracy were calculated (**Table II**). PAS was similarly compared with ultrasound, and histopathology results (**Web Table I**). Diagnostic accuracy (95% CI) of an equivocal PAS (score 4-6) in predicting acute appendicitis in our patients showed sensitivity of 96.8% (90.9-99.3%), specificity of 80% (28.4-99.5%), PPV of 98.9% (94.3-99.8%), and Area under the curve, AUC ( $r=0.84$ ) (**Fig. 1**).

## DISCUSSION

We studied PAS utilized in the pediatric ED of a hospital in a developing country. We used two cut-off points as opposed to Samuel, et al. [7] in his derivation study, where he used a single cut-off point of 5; the rationale for this was to compare amongst groups based on severity, as per the PAS. Another prospective cohort study [11] conducted at a pediatric ED revealed that using two cut-off points for the PAS improves its performance significantly. They set a PAS  $\leq 4$  as low risk for having appendicitis; patients with a score within that margin could be safely discharged (sensitivity of 97.6% and NPV of 97.7%) [11]. They also noticed that a single cut-off point for the PAS overestimated appendicitis and resulted in a negative appendectomy rate of 37.6% [11].

In our study, as a consequence, the low negative appendectomy rates, the negative predictive value and specificity of PAS cannot be assessed properly – the specificity and NPV of PAS is low compared to ultrasound and against gold standards. A similar trend was seen in various other validation studies for the PAS. Goldman, et

al. [9] achieved similar results, at a pediatric ED, when they validated PAS with cut-offs of  $\leq 2$  and  $\geq 7$  for low and high-risk patients with a total AUC of 0.948 in 849 children. A retrospective study [12] at the ED of a community hospital concluded that the diagnostic performance of the PAS in 285 children with PAS  $\geq 7$  had good diagnostic performance, which was comparable to that of abdominal CT imaging, which is the best imaging tool for diagnosis of appendicitis in children. In a prospective study [13] of 140 children in an inpatient setting, a single PAS cutoff of  $\geq 5$  performed better than abdominal ultrasound as a screening tool. Other studies have also reported good performance of PAS in children [10].

Kulik, et al. [8] conducted a systematic review of 12 studies, none of which were in low-to-middle income countries, deriving and validating six different clinical prediction rules (CPR) including the PAS and Alvarado scores using a rigorous 17-item checklist for inclusion. They found that the PAS had been more broadly validated in a variety of settings as compared to the Alvarado score. These included inadequate description of predictor variables and absence of reproducibility testing of predictor variables.

In contrast, Ebell and Shinholser's [14] meta-analysis of 29 studies validating the PAS and Alvarado scores showed that although the latter was able to rule out acute appendicitis in children with a pretest probability  $<60\%$  and a score  $\leq 4$ , PAS failed to demonstrate clinically useful high ( $>85\%$  probability) or low ( $<3\%$ ) risk groups for any pretest probability.

In his derivation set, Samuel, et al. [7] did not set concrete definitions for the parameters of the PAS. For instance, recording of "pain on coughing/hopping/percussion" is subject to the level of training of the healthcare provider obtaining the history and performing the physical examination, and upon time constraints witnessed at a fast-paced site such as the ED. In a retrospective design such as ours, this cannot be accounted for. Cut-offs for pyrexia and neutrophilia are also subject to varying thresholds set by different hospitals and laboratories across the globe.

Further studies are required to validate the PAS in a pediatric population presenting to the ED of a tertiary care center in a developing country, especially taking into account the above-mentioned factors. Our study was a retrospective chart review conducted at a single center, and it had a relatively small sample size. We included patients who presented within 24-hour of onset of acute abdominal pain. In future iteration; however, children with abdominal pain for up to 72 hours should be considered. Inter-observer variability could have been observed due

### WHAT THIS STUDY ADDS?

- The pediatric appendicitis score (PAS) showed good diagnostic accuracy in predicting acute appendicitis in children presenting to the emergency department in a low- and middle-income country.

to patient assessment at the ED by residents of different training levels. Our study center is a large tertiary care hospital that caters to patients from a wide socioeconomic background; hence, under reporting may also have occurred.

In this study we found an equivocal PAS (4-6) to be fairly accurate in predicting acute appendicitis in children presenting to the pediatric ED of a developing country. Thus, potential exists to incorporate the PAS into evidence-based, patient-centric, quality and safety initiatives in the resource-limited pediatric ED, as it has good diagnostic accuracy.

*Ethics clearance:* IEC, Aga Khan University; No.: 4433-EM ERC-16 dated Sept 9, 2016.

*Note:* Additional matter related to this article is available with the web version at [www.indianpediatrics.net](http://www.indianpediatrics.net)

*Contributors:* MS, AIM: helped in conceptualization of the study, devised methodology, developed tool for the study, contributed in training the research assistant for data collection, gave supervision in data collection, input in data analysis, manuscript writing and critically reviewed the manuscript as submitted. OA: data collection and manuscript writing; MJ: data collection; RN: arranging data collection logistics, maintained data folders, manuscript reviewed by all co-authors, drafting the manuscript; SST: cleaned and performed statistical analysis of the data and provided technical input in the data interpretation. All authors have contributed, designed and approved the study.

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**Web Table I Association Between Equivocal Pediatric Appendicitis Score (PAS 4-6) and Histopathology or Ultrasound**

	<i>Histopathology</i>	<i>Ultrasound</i>
Sensitivity	96.81 (90.96-99.34)	89.09 (77.75-95.89)
Specificity	80 (28.36-99.49)	25 (5.49-57.19)
Positive predictive value	98.91 (94.03-99.81)	84.48 (79.5-88.43)
Negative predictive value	57.14 (28.72-81.52)	33.3 (12.67-63.28)

*Values are point estimate (95% CI).*