



## A pre-operative clinical scoring system to distinguish perforation risk with pediatric appendicitis ☆,☆☆,★,★★



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### ABSTRACT

**Importance:** Appendicitis is a common, potentially serious pediatric disease. An important factor in determining management strategy [whether/when to perform appendectomy, duration of antibiotic therapy/hospitalization, etc.] and predicting outcome is distinguishing whether perforation is present.

**Objective:** The objective was to determine efficacy of commonly assessed pre-operative variables in stratifying perforation risk in children with appendicitis.

**Design:** A retrospective analysis of consecutive cases was performed.

**Setting:** The setting was a large urban hospital pediatric emergency department.

**Participants:** Four hundred forty-eight consecutive cases of CT [computerized tomography]-confirmed pediatric appendicitis during a 6-year period in an urban pediatric ED [emergency department]: 162 with perforation and 286 non-perforated.

**Main outcome(s) and measure(s):** To determine efficacy of clinical and laboratory variables with distinguishing perforation outcome in children with appendicitis.

**Results:** Regression analysis identified 3 independently significant variables associated with perforation outcome – and determined their ideal threshold values: *duration of symptoms* > 1 day; *ED-measured fever* [body temperature > 38.0 °C]; *CBC WBC absolute neutrophil count* > 13,000/mm<sup>3</sup>. The resulting multivariate ROC [receiver operating characteristic] curve after applying these threshold values gave an AUC [area under curve] of 89% for perforation outcome [p < 0.001]. Risk for perforation was additive with each additional predictive variable exceeding its threshold value, linearly increasing from 7% with no variable present to 85% when all 3 variables are present.

**Conclusions:** A pre-operative scoring system comprised of 3 commonly assessed clinical/laboratory variables is useful in stratifying perforation risk in children with appendicitis.

Physicians can utilize these factors to gauge pre-operative risk for perforation in children with appendicitis, which can potentially aid in planning subsequent management strategy.

**Level of evidence:** III.

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Appendicitis is a common pediatric disease. An important factor in determining management strategy [whether/when to perform appendectomy, duration of antibiotic therapy/hospitalization, etc.] and

predicting outcome is distinguishing whether appendiceal perforation is present. Physical findings can generically correlate with presence of peritoneal irritation, yet lack specificity for perforation [1]. Radiographic imaging, particularly abdominal CT scan, can accurately aid in stratifying risk; yet is not universally sensitive, nor routinely performed often due to concern for exposing children to ionizing radiation.

Pre-operative assessment for appendicitis perforation risk is multifactorial; integrating aspects of the history, physical examination, laboratory data, and diagnostic imaging. Prior studies [2–19] examined aspects of the clinical assessment to determine predictive value for distinguishing presence vs. absence of appendicitis in children – with variable success. There is a lack of published studies specifically

**Abbreviations:** CT, computerized tomography scan; ED, emergency department; ANC, absolute neutrophil count; ROC curve, receiver operating characteristic curve; CBC, complete blood count; WBC, white blood cell.

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CT

- Appendicitis: visualization of an enlarged appendix measuring  $\geq 7$  mm in diameter in addition to inflammatory signs including hyperemia in the wall, peri-appendiceal fat stranding, or appendicolith
- *Non-perforated* appendicitis: criteria for appendicitis above without any evidence of intra-abdominal abscess/phlegmon, extra-luminal air, extra-luminal appendicolith, or focal defect in enhancing appendiceal wall\*
- *Perforated* appendicitis: criteria for appendicitis above with evidence of either intra-abdominal abscess/phlegmon, extra-luminal air, extra-luminal appendicolith, or focal defect in enhancing appendiceal wall\*

\*Reference 19

Fig. 1. CT radiologic criteria for diagnosing appendicitis and distinguishing perforation status\*.

assessing efficacy of variables in distinguishing the presence vs. absence of perforation in children with appendicitis.

The purpose of this study is to determine efficacy of commonly assessed pre-operative variables in stratifying perforation risk in children with appendicitis.

## 1. Methods

A review was performed of consecutive children <18 years of age with acute appendicitis evaluated in the Pediatric Emergency Department of Maimonides Medical Center presenting between 2010 and 2015. Studied were those who fulfilled radiographic criteria for CT-diagnosed appendicitis (Fig. 1) [20].

Data analyzed included patient age; gender; days of pre-ED symptoms; ED-measured body temperature [fever defined as any ED temperature measured  $\geq 38$  °C] and other vital signs; ED-performed CBC WBC/differential cell counts, and abdominal CT scan results. CBC [complete blood count] absolute neutrophil count [ANC] and absolute band count [ABC] were calculated. Presence of appendicitis, appendicolith and appendiceal perforation status were determined as per tissue visual inspection per attending-level surgeon/pathologist reports in cases resulting in appendectomy; and per attending-level radiologist interpretation of CT scans in cases which were solely managed medically. In each instance in which laparoscopy was performed, the surgeons' operative report was the ultimate arbiter used to diagnose the presence of appendicitis and perforation status. In cases solely managed medically, admission CT results and surgeons' admitting/discharge diagnoses were used to determine the presence of appendicitis and distinguish perforation status. All CT scans were performed after the administration of oral and intravenous contrast material; patients drank a weight-based amount of a 2% diatrizoate meglumine solution approximately 1–2 h before the scan. Standard dose of 2 mL/kg Omnipaque 200 was administered intravenously.

Each study co-investigator received a comprehensive tutorial regarding guidelines to standardize data gathering prior to reviewing cases. All symptoms listed in the templated medical record were surveyed to determine pre-ED symptom onset [in days]; specifically noting the presence of abdominal pain, nausea, vomiting, fever [temperature  $\geq 38$  °C], anorexia. Also gathered from each case was information from the dictated operative report [surgeon] and histologic report [pathologist], specifically noting whether there was visual evidence of appendiceal perforation.

Our previously published appendicitis study [21] assessed inter-rater agreement in data gathering, randomly selecting 20% of total appendicitis cases which were re-examined by 3 investigators [9 variables identical to those in the present study]. Continuous variables were compared using intra-class correlations while categorical variables were compared using kappa coefficients. The median coefficient of agreement was 1.0 [range 0.8–1.0], indicating excellent agreement.

Appendicitis perforation status on abdominal CT scan was determined by criteria seen in Fig. 1. Abdominal CT scan results were classified as *appendicitis without perforation* when criteria for appendicitis were not associated with any of the following findings: intra-abdominal abscess, phlegmon, extra-luminal air, extra-luminal appendicolith, or focal defect in enhancing appendiceal wall [20].

The study was approved by our Investigational Review Board.

### 1.1. Statistical analysis

Normally distributed data are described in terms of mean [ $\pm$  SD] while categorical data are described in terms of frequency [percent].

Receiver operating characteristic (ROC) curves were generated to compare the strength of association between each predictor and perforation status. The statistical significance of the association was determined using a non-parametric technique similar to the Mann–Whitney *U* test. Multivariate logistic regression with backwards selection was then used to select an optimal set of predictors from the ones which were significant by ROC analysis. Relative sensitivity and specificity at each value of a continuous predictor were examined to establish the ideal threshold or cutoff for that continuous variable. These were then retested using multivariate logistic regression to determine if they remained significant.

All tests were carried out using  $p < 0.05$  as the significance level and were calculated using IBM SPSS Statistics for Windows, version 20 [IBM Corp, Armonk, NY].

## 2. Results

During the study period, there were 448 children with CT-diagnosed appendicitis which represented >95% of all patients with appendicitis. In 14 cases, a CBC was performed without a differential count, resulting in 434 complete medical records. Of these, 162 had appendiceal perforation [105 underwent laparoscopic appendectomy and 57 had medical management only] and 286 patients had appendicitis without

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