Measuring Anatomic Severity in Pediatric Appendicitis: Validation of the American Association for the Surgery of Trauma Appendicitis Severity Grade

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Objective To assess whether the American Association for the Surgery of Trauma (AAST) grading system accurately corresponds with appendicitis outcomes in a US pediatric population.

Study design This single-institution retrospective review included patients <18 years of age (n = 331) who underwent appendectomy for acute appendicitis from 2008 to 2012. Demographic, clinical, procedural, and follow-up data (primary outcome was measured as Clavien-Dindo grade of complication severity) were abstracted. AAST grades were generated based on intraoperative findings. Summary, univariate, and multivariable regression analyses were performed to compare AAST grade and outcomes.

Results Overall, 331 patients (46% female) were identified with a median age of 12 (IQR, 8-15) years. Appendectomy was laparoscopic in 90% and open in 10%. AAST grades included: Normal (n = 13, 4%), I (n = 152, 46%), II (n = 90, 27%), III (n = 43, 13%), IV (n = 24 7.3%), and V (n = 9 2.7%). Increased AAST grade was associated with increased Clavien-Dindo severity, P =.001. The overall complication rate was 13.6% and was comprised by superficial surgical site infection (n = 13, 3.9%), organ space infection (n = 15, 4.5%), and readmission (n = 17, 5.1%). Median duration of stay increased with AAST grade (P < .0001). Nominal logistic regression identified the following as predictors of any complication (P < .05): AAST grade and febrile temperature at admission.

Conclusions The AAST appendicitis grading system is valid in a single-institution pediatric population. Increasing AAST grade incrementally corresponds with patient outcomes including increased risk of complications and severity of complications. Determination of the generalizability of this grading system is required. *(J Pediatr 2017;■■:■■-■■).*

Appendicitis is the most common surgical emergency in children.[1] Current methods for the diagnosis of appendicitis use various clinical prediction models such as the Alvarado score and the Appendicitis Inflammatory Response score and others.[2-6] These methods are preoperative diagnostic tools and do not provide meaningful information regarding the anatomic severity of the disease process.[7,8] Thus, clinical prediction tools modeled from various parts of patients' clinical data may not reflect the actual anatomic severity of the disease process. Owing to the lack of a standardized and generalizable grading system that incorporates the anatomic extent of the disease process, it is difficult to investigate how the disease impacts on different patient populations with diverse operators, hospitals, and healthcare systems to produce different outcomes.

To address the lack of standardization the American Association for the Surgery of Trauma (AAST) created an operative grading system to categorize severity of surgical disease.[8] The grading system is similar to the well-validated Organ Injury Scale, which is used to assess organ injury severity in trauma. Grade of injury correlates with clinical outcomes.[9] Previous work demonstrated that the AAST grading system for appendicitis can effectively categorize severity by a multilevel grade (I-V) in adults, with grade associated with key clinical outcomes including duration of stay, type of operation, complications, and mortality.[8,10,11] This appendicitis grading system addresses the lack of granularity afforded by the traditional approach to classifying appendicitis as either complicated or uncomplicated disease.[12] Furthermore, the appendicitis AAST grade has demonstrated validity in adult patients in a multinational cohort, thereby suggesting that it is a generalizable method.[13]

The AAST grading system for severity of appendicitis, however, has not been validated in children with appendicitis. The purpose of this study was to determine whether the AAST grade is sufficient to accurately assign disease severity, which corresponds with outcomes in pediatric appendicitis. We hypothesized that AAST appendicitis grading would be effective in assigning disease severity and that

AAST American Association for the Surgery of Trauma

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appendicitis severity as assigned by AAST grade would be associated with key clinical outcomes such as mortality, morbidity, Clavien-Dindo grade, and duration of stay.

Methods

This was a retrospective single-institution cohort study. Institutional Review Board approval was obtained before conducting the study. Children <18 years of age who underwent appendectomy for acute appendicitis from 2008 to 2012 at Mayo Clinic, Rochester, Minnesota, were included. Children with diagnoses of inflammatory bowel disease, incidental appendectomy, or those without the preoperative diagnosis of appendicitis were excluded. Patients who underwent nonoperative management inclusive of drains and antibiotic therapy were not reviewed. Those receiving interval appendectomies were not included.

Baseline demographic information, body mass index, prehospital symptoms and duration, admission vital signs, admission laboratory data, operative approach (McBurney incision, laparoscopy), complications, overall duration of stay, and 30-day mortality rates were recorded. Complications were recorded using both National Surgical Quality Improvement Program definitions[13] and Clavien-Dindo grade.[14] The primary outcome was complication severity as defined by Clavien and Dindo.

AAST grades (**Table I**) were independently assigned from patients' operative report findings by 2 reviewers. Discrepancies were resolved with a third reviewer. The final AAST grade was used for all outcome analyses.

Statistical Analyses

Continuous variables were described using means with SD if normally distributed and medians with IQRs if gross skewness was present. Categorical variables were summarized as proportions. Univariate analyses to assess the relationship of AAST grade and clinical outcomes were performed using Fisher exact, nonparametric, and ANOVA tests. Variables on univariate analyses with $P < .05$ were included in a multivariable nominal regression analysis to determine risk factors predictive for the development of postoperative complication. Inter-rater reliability was determined using the kappa coefficient, with 95% CIs.[10] Inadequate agreement between reviewers was considered <0.60. The degree of agreement was considerate moderate (0.60-0.79), substantial (0.80-0.89), and almost perfect (>0.91). All data analyses were performed using JMP (SAS Institute, Inc, Cary, North Carolina). GraphPad Prism (GraphPad Software, Inc, La Jolla, California) was used for all visual graphics.

Table I. AAST anatomic severity grades and description[9]

Grades	Operative AAST description of appendicitis
Normal	Normal appendix
Grade I	Acutely inflamed appendix intact
Grade II	Gangrenous appendix intact
Grade III	Perforated appendix with local contamination
Grade IV	Perforated appendix with periappendiceal phlegmon or abscess
Grade V	Perforated appendix with generalized peritonitis

Results

From 2008 to 2012, 331 patients undergoing surgical management of acute appendicitis were identified with a median age of 12[8-15] years; 46% were female. Most patients underwent laparoscopic appendectomy (n = 298, 90%). Open appendectomy using a McBurney incision was performed in 10% (n = 33). The overall complication rate was 13.6% (n = 45). The most frequent complications were superficial surgical site infection (n = 13, 3.9%), organ space infection (n = 15, 4.5%), and readmission (n = 17, 5.1%). There were no deaths within 30 days and no patients required reoperation. Median overall duration of stay was 2 days (IQR, 1-2).

Patients presented with varied duration of symptoms (median, 2 days; IQR, 1-4). At admission the mean temperature was 37.1 ± 0.82°C, white blood cell count was 14.8 ± 4.85, heart rate was 90 ± 12.1 bpm. **Table II** presents detailed data regarding overall characteristics, presentation, surgical methods, and postoperative outcomes.

AAST grades generated from operative report data included: Normal (n = 13, 4%), grade I (n = 152, 46%), grade II (n = 90, 27%), grade III (n = 43, 13%), grade IV (n = 24 7.3%), grade V (n = 9 2.7%). With regard to interrater reliability for AAST grade assignment, the degree of association (kappa coefficient) was 0.79 (95% CI, 0.76-0.83) with 262 of 331 patient grades concordant between the 2 independent reviewers. A third reviewer evaluated the discordant 69 patients and arbitrated AAST grades to generate a final AAST grade for all patients.

AAST grade was associated with patient sex, duration of symptoms, temperature on admission, and white blood cell count(**Table II**). Higher AAST grade was associated with a longer duration of stay and an increased risk of organ space infection. Although the use of open appendectomy increased from 5% of patients with grade I appendicitis to 25% of patients with grade IV, no patients with grade V appendicitis required open appendectomy. Grade for grade, duration of symptoms correlated with surgical approach (**Figure**). The **Figure** also demonstrates that increased grade was associated with both increased complication severity and duration of stay. On multivariable analysis the odds (95% CI) of postoperative complications increased with AAST grade with the exception of grade V (**Table III**). Using grade I as the reference, patients with grade II had 1.1 (95% CI, 1.0-2.7) odds of complications and those with grade IV had 3.3 (95% CI, 1.1-8.8) odds. The greatest association of risk factor with postoperative complications was fever at admission (3.8; 95% CI, 1.1-12.1).

Discussion

Emergency general surgery diseases display significant variability in patient presentation, severity, and outcomes.[16] As-

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