



## Risk stratification in pediatric perforated appendicitis: Prospective correlation with outcomes and resource utilization



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### ABSTRACT

**Purpose:** Despite a wide spectrum of severity, perforated appendicitis in children is typically considered a single entity in outcomes studies. We performed a prospective cohort study to define a risk stratification system that correlates with outcomes and resource utilization.

**Methods:** A prospective study was conducted of all children operated for perforated appendicitis between May 2015 and December 2016 at a tertiary free-standing university children's hospital. Surgical findings were classified into one of four grades of perforation: I. localized or contained perforation, II. Contained abscess with no generalized peritonitis, III. Generalized peritonitis with no dominant abscess, IV. Generalized peritonitis with one or more dominant abscesses. All patients were treated on a clinical pathway that involved all points of care from admission to final follow-up. Outcomes and resource utilization measures were analyzed using Fisher's exact test, Kruskal-Wallis test, One-way ANOVA, and logistic regression.

**Results:** During the study period, 122 patients completed treatment, and 100% had documented follow-up at a median of 25 days after operation. Grades of perforation were: I, 20.5%; II, 37.7%; III, 10.7%; IV, 31.1%. Postoperative abscesses occurred in 12 (9.8%) of patients, almost exclusively in Grade IV perforations. Hospital stay, duration of antibiotics, TPN utilization, and the incidence of postoperative imaging significantly increased with increasing grade of perforation.

**Conclusion:** Outcomes and resource utilization strongly correlate with increasing grade of perforated appendicitis. Postoperative abscesses, additional imaging, and additional invasive procedures occur disproportionately in patients who present with diffuse peritonitis and abscess formation. The current stratification allows risk-adjusted outcome reporting and appropriate assignment of resource burden.

**Level of evidence:** I (Prognosis Study).

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Appendicitis is the most common acute surgical disease encountered by pediatric surgeons [1]. Perforated appendicitis (PA) comprises approximately 25%–30% of appendicitis cases and has historically been considered a single disease entity despite important disparities in outcomes and resource utilization [1,2].

Current clinical scoring systems for appendicitis, such as the Pediatric Appendicitis Score and the Alvarado score, focus on diagnosis of the disease, rather than its severity [3,4]. Attempts have also been made to achieve a standard definition for perforated appendicitis [5]. However, a recent review of the outcomes of perforated appendicitis in the

NSQIP pediatric database revealed persistent significant variability in the outcomes of perforated appendicitis owing to lack of utilization of an evidence-based definition [6]. Every surgeon who treats appendicitis knows that perforated appendicitis represents a wide spectrum of disease, from early perforations with minimal peritoneal contamination to late perforations with abscess formation and diffuse fibrinopurulent peritonitis. Yet, this spectrum is not objectively defined or widely used in outcomes reporting or assessment of treatment protocols.

Our group has been interested in decreasing variability of care in pediatric perforated appendicitis for the last three decades [7–10]. During the last several years, we have focused our work on evidence-based definitions of disease severity and analysis of outcome determinants [10–12]. In the current study, we prospectively validated the ability of a grading system for perforated appendicitis to predict outcomes and resource utilization associated with treatment of the disease. We

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believe such a grading system can finally standardize outcomes reporting, and accurately reflect the resource burden across the disease spectrum.

## 1. Methods

### 1.1. Treatment protocol

In 2015, our group further standardized our previously reported protocols for the treatment of perforated appendicitis [8–10]. Our new protocol covers all points of care from admission to final resolution of the disease and any complications. This includes the operative details, criteria for use of total parenteral nutrition and percutaneously inserted central catheters (PICC), and criteria for postoperative imaging and use of invasive procedures. The full protocol is shown in Appendix A, but its highlights are as follows. Patients diagnosed with perforated appendicitis on clinical evaluation with or without imaging are started on triple antibiotic therapy (ampicillin, tobramycin, and metronidazole), which is continued in the postoperative period. An appendectomy is performed on an urgent, but nonemergent, basis. Nonoperative management is reserved for patients with an appendiceal mass who have been symptomatic for more than five days, and have no evidence of diffuse peritonitis or abdominal distension on exam. In our practice, these patients constitute a small minority (<5%) of those with perforated appendicitis. Patients are continued on intravenous antibiotics in hospital until their ileus resolves, they are afebrile (<37.5 °C for at least 24 h), and have a normal white blood cell (WBC) count.

Our service had not used intraoperative peritoneal cultures in patients with perforated appendicitis for more than two decades. Owing to concerns over emergence of resistant organisms, our revised protocol included peritoneal cultures [13]. An audit of 56 patients performed after six months revealed that all cultured organisms were susceptible to the antibiotic regimen used. Peritoneal cultures led to a change in the antibiotic regimen in only one patient, who was diabetic. Cultures were therefore discontinued for the remainder of the study.

A major component of the new protocol is an intraoperative assessment of grade of perforation by the operating surgeon, as shown in Table 1. A localized or early perforation is diagnosed when the perforation is completely encased by omentum or surrounding structures, or results in free purulence only adjacent to the appendix. An abscess is defined as a discrete and distinct collection of contained pus. Generalized peritonitis is defined as purulence involving two or more of the 5 regions of the abdomen (pelvis, right lower quadrant, left lower quadrant, right upper quadrant/subdiaphragmatic space, left upper quadrant/subdiaphragmatic space). In the operating room, the surgeon also records the presence of a free fecalith and the presence of intestinal dilatation significant enough to qualify as a bowel obstruction or severe ileus.

Parenteral nutrition is initiated in patients with Grade III or IV perforation and severe ileus or bowel obstruction. Peripherally inserted central catheters (PICCs) are installed if patients require parenteral nutrition or have poor intravenous access. PICC placement was not considered an invasive procedure for purposes of the analysis. Patients who demonstrate resolution of fever, ileus, and abdominal tenderness, but persistence of leukocytosis, receive a minimum of five days of intravenous antibiotics before consideration of discharge on oral antibiotics. Imaging for suspicious postoperative abscesses is not performed prior to the 7th postoperative day unless the patient shows no significant

improvement from the preoperative state. Ultrasound is always the first modality when imaging is indicated. Percutaneous drainage of postoperative abscesses is only used if the initial abscess volume is  $\geq 100 \text{ cm}^3$  or there is a lack of response to antibiotics with a smaller abscess amenable to drainage. Operative drainage is undertaken if a retained fecalith is diagnosed or there is failure of percutaneous drainage.

All patients are followed two to four weeks after discharge in the surgical clinic, and the status of their wounds and abdominal exams is clearly documented.

### 1.2. Data collection

Data were prospectively collected on each patient starting at diagnosis and ending at the last postoperative clinic follow-up visit. Enrollment of study patients started in May, 2015 and continued until December, 2016. Data collection was detailed and included clinical presentation and work-up, intraoperative findings, antibiotic treatment, intravenous access and TPN use, discharge criteria, outcomes, and follow-up.

### 1.3. Statistical analysis

The study population was stratified into four groups by grade of perforation. The primary outcome was postoperative abscess development. Secondary outcomes included duration of postoperative ileus, duration of postoperative fever, wound infection, readmission, and total length of hospital stay (defined as length of stay during initial admission plus length of stay for any readmissions). Resource utilization measurements included duration of postoperative antibiotics, duration of postoperative narcotic analgesia use, use of parenteral nutrition, incidence of postoperative imaging, and incidence of postoperative invasive procedures.

All endpoints were analyzed using Fisher's exact test, Kruskal–Wallis test, or one-way ANOVA, as appropriate. A P-value <0.05 was deemed statistically significant. All analyses were done on STATA/MP 13.0 (Statacorp, TX).

### 1.4. Study approval

The study was approved by the Pediatric Research Ethics Board of the McGill University Health Centre Research Institute (14-483-PED).

## 2. Results

### 2.1. Patient cohort

During the study period, 122 consecutive patients underwent operation for perforated appendicitis. The clinical and operative details of the patient cohort are shown in Table 2. Patients with generalized peritonitis (grades III and IV) constituted 41.8% of the cohort. Twenty-three (18.9%) patients were transferred from an outside health care facility. The final clinic follow-up visit was documented in 100% of patients at a median of 25 days (interquartile range 17–39 days).

Abdominal distention and diffuse abdominal tenderness were significantly more common in patients with grades III and IV perforations. While median white blood cell count did not differ between the groups, a higher neutrophil percentage was found in those with grades III and IV perforation. Ultrasound was obtained in 58% of patients, while CT scan was rarely used. Laparoscopic appendectomy was initially attempted in all cases and completed in 117 (96%) of patients. Five patients (4%) required conversion from laparoscopy to laparotomy. Four of these five patients had grade IV perforations. A free fecalith was much more likely to be found in those with grades III and IV perforations. The difference in operative time between the four groups was statistically significant ( $p = .003$ ). Grade III or IV perforation was associated with the intraoperative identification of severe ileus or bowel obstruction in three quarters of patients ( $p < 0.001$ ).

**Table 1**  
Grade of perforation definitions.

Grade of Perforation	Operative Findings
I	Localized or contained perforation
II	Contained abscess with no generalized peritonitis
III	Generalized peritonitis with no dominant abscess
IV	Generalized peritonitis with one or more dominant abscesses

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