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Standardization of care for pediatric perforated appendicitis improves outcomes

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ABSTRACT

Background: The treatment of perforated appendicitis in children is characterized by significant variability in care, morbidity, resource utilization, and outcomes. We prospectively studied how minimization of care variability affects outcomes.
Methods: A clinical pathway for perforated appendicitis, in use for three decades, was further standardized in May 2015 by initiation of a disease severity classification, refinement of discharge criteria, standardization of the operation, and establishment of criteria for use of postoperative total parenteral nutrition, imaging, and invasive procedures. Prospective evaluation of all children treated for 20 months on the new fully standardized protocol was conducted and compared to a retrospective cohort treated over 58 months prior to standardization. Differences between outcomes before and after standardization were analyzed using regression analysis techniques to adjust for disease severity.
Results: Median follow-up time post discharge was 25 and 14 days in the post- and prestandardization groups, respectively. Standardization significantly reduced postoperative abscess (9.8% vs. 17.4%, $p = 0.001$) and hospital stay ($p = 0.002$). Standardization reduced the odds of developing a postoperative abscess by four fold.
Conclusion: Minimizing variability of care at all points in the treatment of perforated appendicitis significantly improves outcomes.
Type of study: Prospective Cohort Study.
Level of evidence: Level II.

Appendicitis is the most common acute surgical disease encountered by pediatric surgeons, and the most common reason for acute surgical admission to a pediatric surgery service [1]. Yet, the management of acute appendicitis has been recalcitrant to standardization, especially in the condition's most complex forms [1–4]. Perforated appendicitis, which occurs in approximately 25%–30% of patients presenting with acute appendicitis, has been characterized by wide variations in care and wide disparities in outcomes [5–7]. These variations exist even between surgeons in a single institution. Clinical practice guidelines have been shown to decrease these variations, decrease resource utilization, and improve outcomes [8].

Our group has been interested in decreasing variability of care for all stages of appendicitis for the last 30 years. We published our outcomes on several occasions during this period, most recently in 2014 [9–13]. After finding a significant increase in the postoperative intraabdominal abscess rate, as well as the use of postoperative invasive procedures, in our most recent study, we embarked on further standardization of all points of care. Our hypothesis was that this further standardization would improve outcomes. We tested this hypothesis in a prospective study conducted over 18 months, and we present our results in this report.

1. Methods

1.1. Treatment protocol

Our perforated appendicitis treatment protocols have been previously published [10,11,13]. Briefly, patients are started on triple antibiotic therapy (ampicillin, tobramycin, metronidazole) once the diagnosis is made and continued on the same in the postoperative period. An appendectomy is performed on an urgent, not emergent, basis. Nonoperative management, used in a very small minority of patients with perforated appendicitis (<5%), is reserved for patients with an appendiceal mass who have been symptomatic for more than 5 days, and have no evidence of diffuse peritonitis or abdominal distension on

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exam. Patients are continued on intravenous antibiotics as inpatients until their ileus resolves, they are afebrile (≤37.5 °C for 24 h), and they have a normal white blood cell (WBC) count. Prior to standardization, discharge on oral antibiotics, postoperative imaging, and use of postoperative abscess drainage procedures were left to the discretion of the attending staff surgeon or pediatric surgical fellow.

After publication of our 2014 report and an extensive literature review, the six attending pediatric surgeons who perform appendectomies achieved consensus to further standardize all points of the treatment protocol. The new protocol is attached as Appendix 1. The major areas of further standardization were:

1. Antibiotic Utilization: Aminoglycoside dosing was changed from a dose of 2.5 mg/kg q 8 h to a dose of 7.5 mg/kg q 24 h. Metronidazole dosing was changed from a dose of 10 mg/kg q 8 h to a dose of 30 mg/kg q 24 h.
2. In the operating room, the surgeon was to grade perforated appendicitis as follows:
   Grade I: early or contained perforation.
   Grade II: Contained abscess with no diffuse peritonitis.
   Grade III: Generalized peritonitis with no dominant abscess.
   Grade IV: Generalized peritonitis with one or more dominant abscesses
3. In the operating room, the surgeon was to record if a free fecalith was encountered and whether significant intestinal dilatation existed to qualify as a bowel obstruction or severe ileus.
4. The surgical procedure was standardized to include the following, and the surgeon had to complete a checklist to indicate that the steps were completed or were not applicable

1) Retrieve fecalith identified on preoperative imaging
2) Remove any free fecalith intact
3) Inspect omentum to confirm no contained fecalith or appendiceal portion
4) Inspect all four quadrants and suction purulence where needed
5) Inspect perihepatic space and suction purulence
6) Retract rectosigmoid out of the pelvis and suction cul de sac
7) Run the bowel and evacuate any interloop abscesses.
8) Confirm removal of entire appendix

5. Pus was cultured and consideration was given to change antibiotic coverage per cultures results if required in a patient who was showing a poor response to therapy. Previously, no pus cultures were taken. An audit was planned after six months.
6. Total parenteral nutrition (TPN) was recommended only for patients with Grade III or IV perforation *and* severe ileus or bowel obstruction.
7. Peripherally inserted central catheters (PICCs) were placed only if patients required TPN or had poor intravenous access.
8. Patient who demonstrated resolution of fever, ileus, and abdominal tenderness, but persistence of leukocytosis, had to receive a minimum of 5 days of intravenous antibiotics before consideration of discharge on oral antibiotics.
9. Oral antibiotics were standardized to ampicillin/clavulinic acid or trimethoprim sulfamethoxazole and metronidazole, in penicillin-allergic patients.
10. Imaging for suspicious postoperative abscesses was not performed prior to the 7th postoperative day unless the patient showed no significant improvement from the preoperative state.
11. The first postoperative imaging modality was always ultrasound, and the requisition was standardized to ask for the following information:
    a. Presence or absence of abscess
    b. Single or multiple abscesses
    c. Largest dimension of single abscess or the largest of multiple abscesses
    d. Volume of single abscess or total volume of multiple abscesses
    e. Presence or absence of a fecalith
    f. Presence or absence of distended bowel
12. Percutaneous drainage of postoperative abscesses was used only if the initial abscess volume was >100 cm^3 or there was a lack of response to antibiotics with a smaller abscess amenable to drainage.
13. All discharges had to be approved by the treating surgeon.

1.2. Data collection

All staff surgeons, fellows, and residents on the pediatric surgery service were oriented to the new protocol prior to commencement of prospective data collection. Data were collected on each patient prospectively starting with the time of diagnosis until the postoperative clinic follow-up visit. Enrollment of study patients started in May, 2015 and continued until December, 2016. Data collection was detailed and included presentation and work-up, operative details, antibiotic treatment, intravenous access and TPN use, discharge criteria, outcomes, and follow-up.

1.3. Cohort comparison

The prospective cohort treated on the new standardized protocol between May, 2015 and December, 2016 was compared to the retrospective cohort treated prior to the new protocol between November, 2008 and August, 2013. A sample size calculation, done prior to the commencement of this study, determined that 110 patients would be needed in the prospective cohort to be compared to 282 historical controls, to demonstrate a 67% decrease in absence rate, with power of 0.80 and type 1 error 0.05.

1.4. Statistical analyses

Our primary outcome was postoperative abscess formation. Secondary outcomes included wound infection, readmission, total length of hospital stay (defined as length of stay during initial admission plus length of stay for any readmissions), and incidence of postoperative invasive procedures (defined as interventional radiological drainage or surgery).

Differences between prestandardization (PRE-S) and post-standardization (POST-S) groups were analyzed using T-Test, Chi-Square, Fisher's Exact, and Kruskal–Wallis Tests as appropriate. Outcomes and resource utilization before and after standardization were analyzed using simple and multiple regression techniques. The adjusted multiple regression model included adjustment for disease severity (grade of perforation and presence of free fecalith), WBC at presentation, symptom duration, and operating surgeon. A p-value of <0.05 was deemed statistically significant. All analyses were performed on STATA / MP 13.0 (StataCorp, College Station, TX).

1.5. Study approval

This 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 cohorts

The POST-S cohort included 122 consecutive patients who underwent appendectomy for perforated appendicitis and were evaluated prospectively. This cohort was compared to the 282 patients in PRE-S group studied retrospectively and previously published [13]. Median follow-up after discharge was 14 days and 25 days, in the PRE-S and POST-S groups, respectively. All patient in the POST-S group had documented follow-up to recovery. A comparison of the PRE-S and POST-S cohorts with respect to demographics, symptoms, laboratory work-up, imaging, and operative details is shown in Table 1.