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# Evaluating the effect of time process measures on appendectomy clinical outcomes☆,☆☆,☆☆☆,☆☆☆☆

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ABSTRACT

*Background:* With varied reports on the impact of time to appendectomy on clinical outcomes, we examined the effects of pre-operative delays in pediatric acute appendicitis.
*Methods:* Children with acute appendicitis (January 2013–June 2014) were identified from a prospective database. Univariate analyses compared time metrics, patient characteristics, and disease severity with postoperative complications (POC) and organ space surgical site infection (OSSI), and multivariate logistic regression determined predictors of POC and OSSI.
*Results:* 1211 patients underwent appendectomy. Median age was 10.4 years (IQR 7.8–13 years). 537 patients (45%) had complex appendicitis. Overall, POC was 11% (n = 133), and OSSI was 9% (n = 105). Neither time from presentation to appendectomy nor diagnosis to appendectomy increased POCs. On univariate analyses, operative time (OT) was longer in patients with POC (57 min (IQR 49–75) vs. 46 min (IQR 36–57), $p < 0.001$ and OSSI (60 min (IQR 51–80) vs. 46 min (IQR 37–57), $p < 0.001$. However, after adjusting for confounding factors, disease severity remained the most significant predictor of POC (OR 6.5, 95% CI 2.79–15.23) and OSSI (OR 76.6, 95% CI 7.87–745.65).
*Conclusion:* Pre-operative delays were not associated with increased POC or OSSI. The strongest predictor of POC or OSSI was disease severity, for which operative time may represent a surrogate.


## 1. Background

The appropriate timing of appendectomy has been debated among pediatric surgeons. While some believe that appendectomies should be performed emergently, others contend that short delays allow for patient optimization and do not correlate with poor outcomes. The adult and pediatric literature is divided between these two approaches. Some studies advocate for immediate appendectomy after diagnosis to minimize risk of perforation and postoperative surgical site infections [1,2]. Others propose delaying surgery for 12–24 h to allow for adequate resuscitation of patients and lessen surgeon fatigue from operating overnight [3–5].

We perform approximately 1200 appendectomies annually at our institution. These operations comprise the largest proportion of urgent abdominal operations performed, and cumulatively, they are associated with high direct variable costs, being second only to extracorporeal membrane oxygenation (ECMO) in a recent internal key process analysis of costs. Given this high volume, quality improvement initiatives are critical in improving efficiency of appendectomy patient care, as minor improvements may have larger clinical implications. We have established a system for real-time tracking of prospective appendectomy outcomes utilizing an Electronic Data Warehouse (EDW). This clinical program datamart draws information from the electronic medical record, administrative, financial and multiple other sources, and using linkable identifiers then generates data visualizations on designated outcome measures. A balanced scorecard of outcomes was produced in a robust metric development process involving all stakeholders, including process measures, such as time from presentation to diagnosis, diagnosis to administration of antibiotics, and diagnosis to surgery. Optimizing these process metrics may play a role in streamlining patient care and potentially improving patient outcomes. As such, in an effort to prioritize quality improvement interventions, we sought to analyze

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the effect of these perioperative time metrics, particularly time from presentation to surgery and from diagnosis to surgery, on patient outcomes.

## 2. Methods

### 2.1. Patient population

After IRB approval (H-33,167), pediatric patients (≤18 years of age) who underwent an appendectomy at our institution from January 1, 2013 to May 31, 2014 were evaluated by querying the institutional Electronic Data Warehouse. Patients treated at our satellite campuses as well as those who underwent an interval appendectomy or incidental appendectomy were excluded from the study. All patients were managed according to a hospital-wide, evidence-based practice guideline for management of patients with appendicitis, thus minimizing variability in all phases of care.

### 2.2. Study design and clinical variables

The study was a retrospective chart review. Data collected included demographics, American Society of Anesthesiology (ASA) classification system score, body mass index (BMI), duration of symptoms, white blood cell (WBC) count on admission, process time metrics (time from presentation at the emergency department to appendectomy, time from diagnosis to appendectomy, operative time), operative findings, intraoperative disease severity, and postoperative outcomes. Time of diagnosis was defined in our EDW as the time the appendectomy case was scheduled. This was the electronic time stamp that best represented surgical evaluation of the patient and establishment of the diagnosis of appendicitis. Of note, appendectomies are not generally performed after midnight at our institution. Patients evaluated after hours for appendicitis are scheduled on the emergency case list for the following morning. Disease severity was stratified into two categories, simple (acute, suppurative) or complex (gangrenous, perforated), and was determined using the surgeon's intraoperative diagnosis. The intraoperative, as opposed to pathologic diagnosis, was chosen as the reference as it has been more closely correlated with clinical outcomes in our experience [6]. Primary outcomes included organ/space surgical site infection (OSSI) and any 30-day postoperative complications (POC), namely urinary tract infection, superficial incisional and deep incisional surgical site infection, superficial and deep wound disruption/dehiscence, unplanned reoperation, and postoperative septic shock as defined by the National Surgical Quality Improvement Program (NSQIP) [Table 1] [7]. These outcomes were adjudicated by review of the electronic medical record for postoperative complications in the index admission and any subsequent clinical encounter (ED visit, readmission, and/or clinic visit) within our hospital system up to 30 days postoperatively. 30-day postoperative complications were assessed such that multiple complications in a single patient were counted as one POC. Follow-up was determined by date of the postoperative assessment either through clinic visits or nurse phone calls, per our routine practice.

### 2.3. Statistical analyses

Statistical analyses were performed using SPSS (Version 22.0, SPSS Inc., Armonk, NY). Univariate analyses were performed to evaluate the association between the various time metrics (time from presentation to surgery, time from diagnosis to surgery, operative time) and 30-day postoperative complications and OSSI. Time metrics were analyzed as continuous variables. Continuous variables were analyzed using Student's *t* test or Mann–Whitney *U* test, depending on data normality. Frequency distributions between categorical values were compared using $\chi^2$-analysis. Variables that achieved statistical significance on univariate analyses, as well as those determined from the literature to be associated with increased incidence of 30-day postoperative complications (BMI, length of symptoms, admission WBC, preoperative time metrics, surgical approach, disease severity), were included in a multivariate regression. A p-value of $<0.05$ was deemed statistically significant.

**Table 1**
NSQIP definitions of postoperative complications.

| Postoperative complications assessed | NSQIP definitions |
|---|---|
| Superficial incisional SSI | An infection that involves only skin or subcutaneous tissue of the surgical incision |
| Deep Incisional SSI | An infection, which involves deep soft tissues. Deep soft tissues are any tissue beneath skin and immediate subcutaneous fat (e.g. fascia and muscle layers) |
| Organ/space SSI | An infection that involves any part of the anatomy (e.g. organ or spaces) other than the incision, which was opened or manipulated during an operation |
| Superficial wound disruption/dehiscence | A separation of the superficial (external) layer(s) of the surgical wound (e.g. skin, subcutaneous tissue, mucosa) |
| Deep wound disruption/ dehiscence | A separation of the internal (deep) layer(s) of the surgical wound (e.g. fascia, muscle) |
| Urinary tract infection | An infection in the urinary tract within 30 days after the principal operative procedure. Patient without urinary catheter must have: a positive culture ($\geq 10^5$ CFU/ml) with no more than 2 species of microorganisms and one clinical symptom or a positive culture of $\geq 10^3$ and $<10^5$ CFU/ml with no more than 2 species of microorganism and a positive urinalysis and one clinical symptom |
| Postoperative septic shock | A patient who meets criteria for sepsis and meets the criteria for cardiovascular dysfunction |
| Unplanned reoperation | Surgical procedures that started prior to midnight of POD 30 that were not planned at time of principal operative procedure |

## 3. Results

### 3.1. Patient demographics

1211 patients underwent appendectomy during the study period. The majority of patients were males (n = 725; 60%), and the median age was 10.4 years (IQR 7.8–13). The median ASA for the cohort was 1 (IQR 1–2) and median BMI was 19.3 (IQR 16.4–23.4). Six hundred and seventy-four patients had simple appendicitis and 537 patients (45%) had complex appendicitis, of which 409 were perforated and 128 gangrenous. The overall median duration of symptoms prior to presentation was 1 day (IQR 1–2 days). For complex appendicitis patients, the median duration of symptoms was 1 day (IQR 1–2) for gangrenous appendicitis and 2 days (IQR 1–3) for perforated appendicitis. The average white blood cell count (WBC) on admission was $15.8 \pm 5.2 \times 10^9$ white blood cells per microliter (μL). The majority of patients underwent laparoscopic appendectomy (n = 1130; 93%), while 12 patients had open appendectomy (n = 12; 1%) and 69 patients had single incision laparoscopic appendectomy (n = 69; 6%). After surgery, overall median LOS was 1 day (IQR 0–4). When stratified by disease severity, the median postoperative LOS for simple appendicitis patients was 20 h (IQR 15–24) compared to 5 days (IQR 3–7) for those with advanced appendicitis. 128 of the 537 complex appendicitis patients (24%) met institutional criteria for discharge home with oral antibiotics.

### 3.2. Time metrics and clinical outcomes

The median time from presentation to diagnosis was 249 min (IQR 165-398), time from presentation to surgery was 582 min (IQR 398–826), and time from diagnosis to surgery was 264 min (IQR 130–435). Five hundred and twenty-two patients (43%) presented during the evening shift (from 7 p.m. to 7 a.m.). The median overall operative time was 47 min (IQR 37–59). Simple appendicitis patients had