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Beyond perforation: Influence of peritoneal contamination on clinical severity and resource utilization in children with perforated appendicitis

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ABSTRACT

Purpose: The purpose of the study was to explore the relationship between the degree of peritoneal contamination and postoperative resource utilization in children with complicated appendicitis.
Methods: Intraoperative findings were collected prospectively at a single children's hospital from 2012 to 2014. The degree of peritoneal contamination was categorized as either "localized" (confined to the right lower quadrant and pelvis) or "extensive" (extending to the liver). Imaging utilization, postoperative length of stay (pLOS), hospital cost, and readmission rates were compared between groups.
Results: Of 88 patients with complicated appendicitis, 38% had extensive contamination. Preoperative characteristics were similar between groups. Patients with extensive contamination had higher rates of postoperative imaging (58.8% vs 27.7%, $P < 0.01$), a 50% longer median pLOS (6 days [IQR 4–9] vs 4 days [IQR 2–5], $P = 0.003$), a 30% higher median hospital cost ($17,663 [IQR $12,564–$23,697] vs $13,516 [IQR $10,546–$16,686], $P = 0.004$), and a nearly four-fold higher readmission rate (20.6% vs 5.6%, $P = 0.04$) compared to children with localized contamination.
Conclusion: Extensive peritoneal contamination is associated with significantly higher resource utilization compared to localized contamination in children with complicated appendicitis. These findings may have important severity-adjustment implications for reimbursement and readmission rate reporting for hospitals that serve populations where late presentation is common.

Appendicitis is the most common abdominal surgical emergency in children and is associated with relatively high resource utilization [1,2]. Up to 40% of children with appendicitis will present with complicated disease, and this cohort of patients is associated with a relatively high rate of postoperative complications and prolonged hospitalization [3,4]. To date, studies examining the relationship between disease severity and resource utilization following appendectomy have primarily compared outcomes between patients with uncomplicated and complicated appendicitis [5]. Few studies have examined the influence of disease severity on resource utilization specifically within the cohort of children with complicated disease.

The goal of this study was to investigate the relationship between degree of peritoneal contamination in complicated appendicitis and its influence on resource utilization in the postoperative period. We hypothesized that more extensive contamination would lead to more intensive resource utilization, including imaging studies, percutaneous drainage procedures, and narcotic utilization, as well as higher the likelihood of readmission following discharge from the index encounter. Findings to support this hypothesis may have important implications for ensuring adequate reimbursement and fair comparative reporting of readmission rates for hospitals that serve populations where late presentation and more severe disease are common.

1. Methods

1.1. Patient cohort

A retrospective analysis of prospectively collected data was conducted for all patients undergoing appendectomy from 2012 to 2014 at a single free-standing, tertiary children's hospital. All patients presenting with suspected appendicitis had a white blood cell (WBC) count drawn and underwent ultrasound of the right lower quadrant and pelvis. Additional cross-sectional imaging (e.g. computed tomography) was obtained at the discretion of the surgeon if advanced disease or a well-formed abscess was suspected. Nonoperative management in the presence of advanced disease was also at the discretion of the surgeon. Appendectomy was performed by one of 15 pediatric surgeons with technique chosen based on surgeon preference. The final diagnosis of appendicitis was established by histopathologic analysis. At the time of the study, all patients with perforated appendicitis were treated with a 7-day course of

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either intravenous (IV) transitioned to oral antibiotics following discharge or a 7-day course of IV antibiotics only with a PICC line (at the discretion of the operating surgeon). No patients with pathology-proven appendicitis were excluded from the study during the study period. Patients were discharged once they met three criteria: 1) Afebrile for 24 h, 2) tolerating an oral diet well enough to maintain urine output without supplemental IV fluids, and 3) no longer requiring IV pain medication. Follow-up communication was at the discretion of the operating surgeon and parental preferences and included a visit to surgical clinic, phone call follow-up, or visit by the home nursing service in the case when a PICC line was utilized. Preoperative demographic and clinical characteristics collected included age, weight, gender, race, insurance status, white blood cell (WBC) count and highest preoperative temperature. Patient follow-up period was documented as the time of the last clinic visit or phone correspondence. This study was approved by the institutional review board at our institution (#P00012842).

1.2. Severity classification

Appendicitis was considered to be complicated if frankly purulent fluid and fibropurulent exudate was found immediately adjacent to a visibly perforated appendix. The degree of peritoneal contamination was categorized as "localized" if it was confined to the right lower quadrant, retrocecal space or pelvis prior to operative manipulation, and "extensive" if purulent material or fibropurulent exudate was found to physically contact the liver upon initial visualization. In choosing intraoperative findings for differentiating severity, we recognized that other potential criteria could be used for this purpose, including location, size and number of abscesses, among others. We chose to use liver involvement as a marker of more extensive peritonitis and contamination (biofilm seeding of peritoneal surface) as a simple and relatively objective classification scheme for surgeons to report. Surgeons were required to document intraoperative findings within 24 h of the operation using a mandatory, standardized electronic survey linked to our hospital's billing software.

1.3. Outcomes and resource utilization measures

Resource utilization measures collected for the 30-day postoperative period included abdominal imaging (computed tomography or ultrasound), cumulative narcotic dosage, and percutaneous abscess drainage. Narcotic utilization was calculated as the cumulative postoperative dosage of intravenous morphine received (measured in mg/kg) or morphine-equivalent dosage if a patient received other narcotic agents. Postoperative length of stay (pLOS), hospital cost, and rate of readmission to the inpatient setting following discharge from the index encounter were also analyzed.

1.4. Data analysis

Univariate analyses were performed using the Fisher's exact test and Pearson chi-square statistics for categorical data, and the Mann–Whitney *U* test for continuous data. Logistic regression was used to examine the relative influence of peritoneal contamination on outcome measures while adjusting for other covariates (age, weight, gender, race, insurance status, maximum temperature, and WBC count). Statistical significance was set at $P < 0.05$ using a two-tailed distribution. Data analysis was conducted using IBM SPSS software (SPSS version 23.0, IBM, Armonk, NY).

2. Results

A total of 417 patients with pathology-confirmed appendicitis were reviewed, of which 88 (21%) patients had intraoperative findings meeting criteria for complicated appendicitis. Of these, 34 patients (38%) had extensive peritoneal contamination extending to the liver. Demographic and preoperative clinical characteristics were similar between the two groups (Table 1). During the study period, the median number of appendectomies performed by each surgeon was 6 (IQR: 2–6), and 11 (73%) of the 15 surgeons performed appendectomies in patients found to have both localized and extensive peritoneal contamination. The median follow-up period was similar between groups (localized: 19 days [IQR: 13–28] vs. extensive: 23 days [IQR: 18–29], $P = 0.091$). One patient was lost to follow-up in the localized contamination group compared to four patients in the extensive contamination group.

Patients with extensive peritoneal contamination had a 3.7 higher odds of receiving a postoperative abdominal imaging study (95%CI: 1.5–9.2, $P = 0.005$; 58.8% vs 27.8%, $P < 0.01$) and a 2.5 higher odds of a percutaneous drainage procedure (95%CI: 0.4–15.9, $P = 0.32$; 11.8% vs 1.8%, $P = 0.07$) compared to patients with localized contamination, although the latter was not statistically significant. Total narcotic utilization was 47% higher in the extensive contamination group compared to localized contamination, but this difference was not statistically significant (0.22 mg/kg [IQR: 0.09–0.6] vs 0.15 mg/kg [IQR: 0.06–0.42], $P = 0.31$) (Table 2).

Patients with extensive peritoneal contamination had a 30% higher cumulative median hospital cost compared to those with localized contamination ($17,663 [IQR $12,564–$23,697] vs $13,516 [IQR: $10,546–$16,686], $P = 0.004$) and median pLOS was 50% longer for patients with extensive contamination (6 days [IQR: 4–9] vs 4 days [IQR: 2–5], $P = 0.003$) (Fig. 1). The readmission rate was significantly higher in patients with extensive contamination, with a 4.4 higher odds of readmission (95%CI: 1.05–18.43, 20.6% vs 5.6%, $P = 0.04$) compared to those in the localized contamination group (Table 2). Of those who had a revisit, the median time to revisit after discharge was similar between localized and extensive contamination groups (3 days [IQR 2–5] vs 4 days [IQR 4–21], $P = 0.16$).

3. Discussion

In children with complicated appendicitis, our analysis demonstrated that extensive peritoneal contamination was associated with significantly higher resource utilization and hospital cost compared to children with localized disease. These findings included four-fold higher odds of postoperative abdominal imaging, a 50% longer postoperative length of stay, and 30% higher hospital cost. Furthermore, extensive disease was associated with more than a four times higher odds of inpatient readmission within 30 days of appendectomy.

To our knowledge, no study to date has examined the extent of peritoneal contamination and its influence on resource utilization in children with complicated appendicitis. Previous studies have largely focused on comparing resource utilization between complicated and

Table 1
Demographics and clinical characteristics of children found to have localized and extensive peritoneal contamination at the time of operation.

	Localized n = 54 (%)	Extensive n = 34 (%)	*P* value
Age in years*	9 (7, 13.25)	8 (6,11)	0.298
Weight in kg*	32.4 (24.8, 55.3)	31.2 (22.2, 41.3)	0.155
Male (%)	29 (53.7)	18 (52.9)	0.944
Race			0.483
White (%)	34 (63)	17 (50)	
Black/Hispanic (%)	11 (20.4)	9 (26.5)	
Insurance			0.377
Public (%)	13 (24.1)	10 (29.4)	
Commercial (%)	41 (75.9)	24 (70.6)	
Maximum temperature in Celsius*	37.9 (37.2, 38.6)	38.2 (37.6, 39.1)	0.086
White blood cell count (1000 cells/mcL)*	16.3 (13.6, 38.6)	17.3 (14.4, 23.7)	0.324
Laparoscopic appendectomy (%)	52 (96.3)	34 (100)	0.522
PICC placement with home intravenous antibiotics (%)	23 (42.6)	18 (52.9)	0.385

* Value reported as median (interquartile range).