IMPACT OF SURGICAL TIMING ON PEDIATRIC APPENDICITIS OUTCOMES: A RETROSPECTIVE ANALYSIS

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Abstract

Background: Acute appendicitis is one of the most common surgical emergencies in children. The optimal timing of surgery following diagnosis remains debated, with some advocating for immediate intervention while others support delayed appendectomy. This study examines whether surgical timing affects paediatric appendicitis outcomes, particularly in terms of perforation risk, postoperative complications, and hospital stay duration.

Methods: This retrospective study analyzed data from paediatric patients (0–15 years) who underwent appendectomy for suspected appendicitis. Patients were stratified into different groups based on the time elapsed between emergency department (ED) admission and surgery. Primary outcomes included histopathologic confirmation of perforated appendicitis. Secondary outcomes included rates of wound infection, intra-abdominal abscess, reoperation, readmission, and hospital stay length. Multivariate logistic regression analysis was used to adjust for potential confounders, such as inflammatory markers and symptom severity.

Results: Among 2,500 paediatric patients, 24% had histopathologic ally confirmed perforated appendicitis. Factors significantly associated with perforation included younger age, female sex, elevated body temperature, and increased inflammatory markers (CRP, WBC). Unadjusted analysis showed an inverse relationship between time to surgery and perforation risk, but adjusted models revealed no significant association between surgical delay and perforation. Delayed surgery was not linked to higher rates of wound infections, intra-abdominal abscesses, or readmissions. Notably, moderate surgical delays (24–36 hours) were associated with shorter hospital stays.

Conclusion: Surgical timing does not independently impact perforation risk or postoperative complications in paediatric appendicitis cases. These findings support the safety of delayed appendectomy in stable patients, emphasizing the importance of preoperative management, including fluid resuscitation and selective antibiotic use.

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Introduction

Acute appendicitis is among the most frequent surgical emergencies in children. The optimal timing of surgery following diagnosis remains a topic of debate, with differing opinions on whether immediate or delayed appendectomy yields better outcomes. Deferred appendectomy is increasingly employed in healthcare settings lacking on-call paediatric surgical services. In this approach, patients diagnosed with uncomplicated appendicitis after a specific time of day are admitted for stabilization with antibiotics, analgesia, and preparation for surgery the following day (1,2,3). Current evidence suggests that complications arising from this strategy are more closely related to diagnostic delays or late initiation of intravenous antibiotics rather than the time elapsed between admission and surgery (4,5,6).

Despite this, some healthcare canters remain cautious about delayed appendectomy, as certain studies have reported poorer outcomes with deferred surgery. These studies propose that emergency appendectomy, even during late-night hours, might reduce the risk of disease progression and associated complications by minimizing the time from diagnosis to surgery (7,8).

Traditional views of acute appendicitis as a progressive condition that inevitably leads to perforation have been challenged in recent years. Emerging evidence highlights the role of the individual's immune response in disease progression, emphasizing the need to differentiate between patients requiring immediate surgical intervention and those for whom surgery can be safely deferred (9,10,11). This evolving perspective has also opened discussions about the viability of conservative, non-surgical management in certain cases (12,13,14).

The primary goal of this research is to assess whether the timing of appendectomy impacts outcomes in paediatric patients with acute appendicitis, focusing on complications and length of hospital stay. Additionally, the study aims to identify early predictors of gangrenous appendicitis and evaluate whether surgical delay increases histopathologic findings of perforation. Secondary outcomes include rates of wound infection, intra-abdominal abscess, reoperation, readmission, and overall hospital stay duration.

Methods

This study utilized data from a database with prospectively recorded information on children aged 0–15 years who underwent emergency appendectomy for suspected appendicitis. The dataset included patient demographics, hospital administrative records, and detailed preoperative, intraoperative, and postoperative clinical data. Symptom duration prior to hospital presentation was not documented.

The diagnosis of acute appendicitis and the decision for emergency appendectomy were based on clinical history, physical examination, routine inflammatory markers such as C-reactive protein (CRP) and white blood cell (WBC) counts, as well as imaging studies like abdominal ultrasound, with computed tomography used in inconclusive cases.

The preoperative protocol included fasting, rehydration (50 mL/kg over four hours with Ringer's solution), and tailored pain management (acetaminophen and morphine). All patients received prophylactic antibiotics (metronidazole 20 mg/kg). In cases of peritonitis or suspected perforation, antibiotic therapy was initiated at admission, as per the attending surgeon's discretion. For anticipated surgical delays, antibiotics were occasionally administered even in the absence of these conditions. Details of preoperative antibiotic use were not recorded in the database.

Appendectomies were performed using standard open or laparoscopic techniques, as previously outlined (15). Postoperative antibiotic use was guided by findings of gangrenous or perforated appendicitis during surgery.

The interval from emergency department (ED) admission to surgical incision was categorized as the time to surgery. This was determined from the electronic patient records for ED admission and the operating room log for surgery initiation. Patients operated on within 12 hours of ED admission served as the reference group. Delays were classified into three groups: 12–24 hours, 24–36 hours, and over 36 hours. Surgical timing was influenced by factors such as ED case load, the duration of preoperative assessments, symptom severity, and operating room availability, particularly during off-hours.

The primary outcome was the histological confirmation of perforated appendicitis, assessed based on established criteria (16). Secondary outcomes included postoperative wound infection (localized inflammation with or without purulent discharge, managed conservatively or with antibiotics), intra-abdominal abscess (fluid collection detected via imaging after three days, treated with antibiotics or drainage), reoperation (repeat surgical intervention under general anaesthesia), postoperative hospital stay (time from surgery to discharge), and readmission within 30 days of the initial surgery. Data for secondary outcomes were retrospectively gathered during ongoing audit follow-ups.

Statistical Analysis

Univariate analysis was performed to assess the relationship between time to surgery and the outcomes of interest. Categorical data were analyzed using Fisher's exact test, while continuous variables were evaluated with Mann-Whitney U or Kruskal-Wallis tests. Logistic regression models were employed to adjust for selection bias and confounding variables, including markers of disease severity such as CRP, WBC, and body temperature. CRP and WBC were treated as continuous variables, while body temperature was dichotomized using a cutoff of 37.5°C.

To mitigate bias arising from the prioritization of sicker patients for emergency night-time surgeries, the surgical timing was categorized into three periods: midnight to 8:00 AM, 8:00 AM to 4:00 PM, and 4:00 PM to midnight. Statistical analyses were conducted using R software (19).

Results

A total of 2,500 paediatric patients who underwent acute appendectomy for suspected appendicitis were assessed for inclusion. Histopathological data were available for (99.2%) patients, of whom (3.8%) had negative appendectomy findings and were excluded. The remaining patients, all with a confirmed histopathological diagnosis of appendicitis, were included. Among these (24.0%) had perforated appendicitis, while (76.0%) presented with no perforated appendicitis.

Factors associated with histopathologic ally confirmed perforation included younger age, female sex, night-time surgery, elevated body temperature, higher C-reactive protein (CRP) levels, and increased white blood cell (WBC) count at admission (Table 1). In contrast, patients experiencing surgical delays were more likely to be older, have surgeries during daytime, and exhibit lower body temperatures, CRP levels, and WBC counts. Analysing crude data, surgical delays were inversely related to perforated appendicitis.

Unadjusted analysis showed a strong negative relationship between increased time to surgery and the risk of perforated appendicitis. However, adjusted multivariate logistic regression revealed no significant association between surgical delay and the likelihood of histopathological perforation. Furthermore, after adjustment, no statistically significant relationships were found between surgical delay and the occurrence of wound infections, postoperative intra-abdominal abscesses, reoperations, or readmissions. A shorter hospital stay was significantly linked to moderate surgical delays (24–36 hours), but this association was not observed in cases of delays of 12–24 hours or longer than 36 hours.

Analyses using non-imputed datasets in the multivariate logistic regression model produced comparable outcomes, with no significant impact on the main findings.

To account for the possibility that a strict histopathological definition of perforation might exclude certain advanced cases, an additional analysis was conducted. The revised outcome, referred to as "complex appendicitis," included surgical observations of perforation (e.g., perforated appendix, purulent peritonitis, localized abscess) and/or histopathological evidence. This analysis involved 2,500 patients, of whom (3.8%) had negative appendectomy findings and were excluded. The remaining patients included (30.4%) classified as complex and (69.6%) as non-complex. Multivariate logistic regression analysis with this broader definition did not alter the study's primary findings, as no significant link was found between surgical delays and complex appendicitis.

A subgroup analysis was conducted for children younger than five years, who exhibited relatively higher rates of perforation. In the adjusted multivariate logistic regression model, no statistically significant association was found between surgical delays and perforation in this subgroup. A non-significant trend toward an elevated risk of perforation was observed for moderate delays (12–24 hours, adjusted OR 1.75, P = 0.122). Postoperative complications, including wound infections, intra-abdominal abscesses, reoperations, and readmissions, were too infrequent for adjusted analysis in this group. Additionally, surgical delays did not lead to longer postoperative hospital stays for children under five years (Table 1), (Figures)

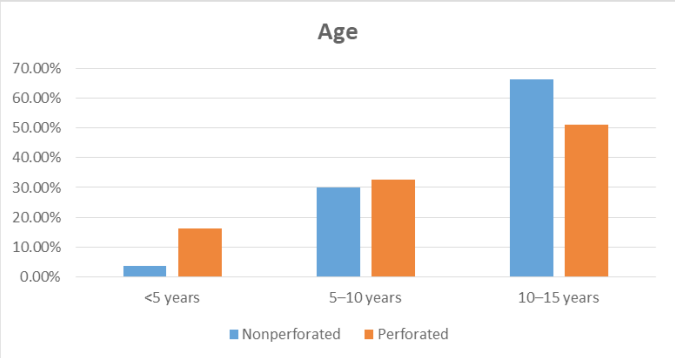
Table 1. Demographics and Clinical Characteristics of the Cohort by Histopathology.

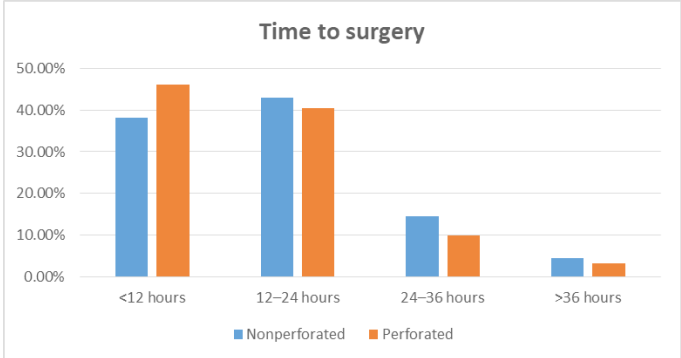
Characteristic	No perforated	Perforated	P Value
Age, (%)			
<5 years	(3.7%)	(16.2%)	<0.001*
5–10 years	(30.0%)	(32.7%)	
10–15 years	(66.3%)	(51.1%)	
Sex, (%)			
Boy	(61.1%)	(55.1%)	0.007*
Girl	(39.0%)	(44.9%)	
Body temperature, (%)			
<37.5°C	(54.2%)	(25.3%)	<0.001*
≥37.5°C	(44.5%)	(73.5%)	
Missing	(1.2%)	(1.2%)	
CRP, mg/L; median (IQR)	19 (8, 43)	82 (38, 149)	<0.001†
Missing	165 (7.9%)	42 (6.4%)	
WBC, 10^9/L; mean ± SD	14.3 ± 4.8	17.1 ± 5.6	<0.001†
Time of operation, (%)			
00:00–08:00	(18.7%)	(22.5%)	0.013*
08:00–16:00	(31.8%)	(26.5%)	
16:00–24:00	(49.5%)	(51.0%)	
Time to surgery, (%)			
<12 hours	(38.1%)	(46.1%)	<0.001*
12–24 hours	(42.9%)	(40.5%)	
24–36 hours	(14.6%)	(10.0%)	
>36 hours	(4.4%)	(3.3%)	
Type of operation, (%)			
Laparoscopic	(74.7%)	(74.6%)	0.959*
Open	(25.3%)	(25.4%)	
Operating time, min; median (IQR)	(33, 61)	(43, 76)	<0.001†
Wound infection, (%)	(1.8%)	(2.6%)	0.199*
Postoperative abscess, (%)	(1.4%)	(13.3%)	<0.001*
Reoperation, (%)	(0.5%)	1(2.0%)	<0.001*
Length of hospital stay, h; median (IQR)	37.4 (23.4, 56.1)	115.1 (87.8, 158.9)	<0.001†
Readmission, (%)	(2.1%)	(10.1%)	<0.001*

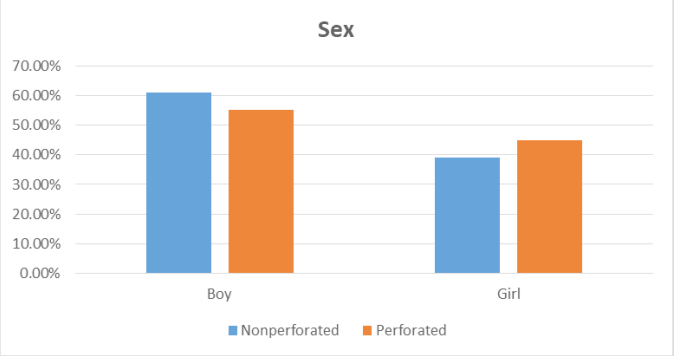
*Fisher's exact test.

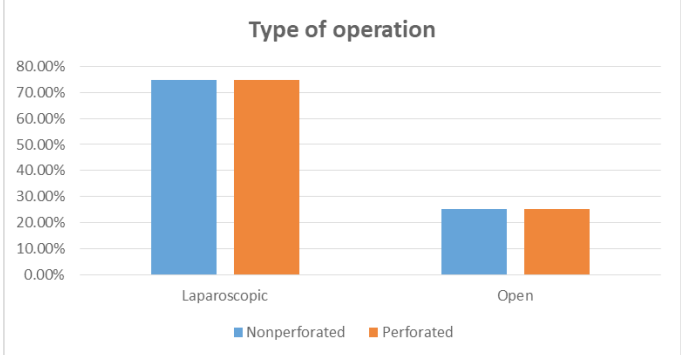
†Nonparametric Mann-Whitney U test.

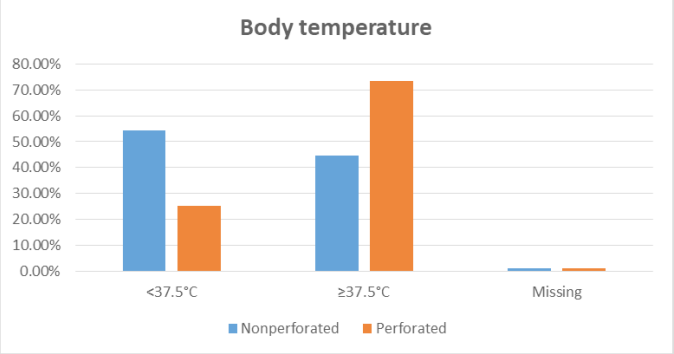
Data presented as mean ± SD for normally distributed data, and median (IQR) for skewed data.

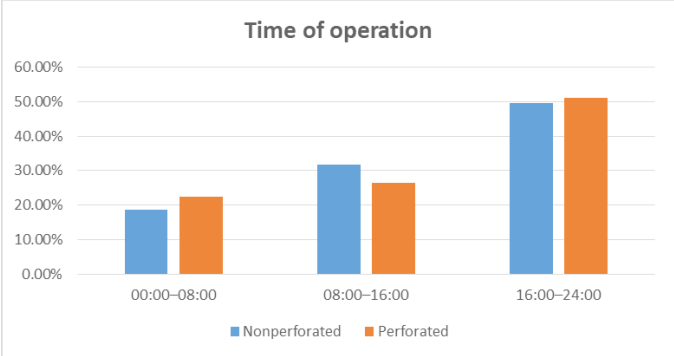












Discussion

The delay in surgery for acute appendicitis in children was not linked to an increased incidence of histopathologic perforation. Additionally, the timing of the surgery was not found to be an independent risk factor for postoperative complications. The degree of surgical delay did not influence the results.

This study has several strengths compared to prior research in paediatric appendicitis, including a large cohort size, a broad inclusion of patients (with only 0.8% missing histopathologic data and 3.8% negative appendectomies excluded), the application of multiple imputation to address missing data, and the ability to adjust for confounders and selection bias. However, being a retrospective study, there was significant bias due to confounding by indication, as those with more severe symptoms were prioritized for emergent surgery. Most perforations were observed in the shorter surgical delay groups, and perforated appendicitis was more common in girls and younger children. To mitigate this, data adjustments were made for factors like age, sex, and disease severity at admission, including markers such as CRP, WBC, and body temperature, which have been independently linked to perforation or severe disease (17) (18).

The study utilized data from a single institution, and since no separate treatment protocol was in place, children were treated according to local practices and individual surgeon decisions. The study lacked detailed information about the duration of symptoms before admission, which would have been valuable in understanding the progression toward perforated appendicitis. Postoperative complications, such as wound infections or intra-abdominal abscesses, were assessed retrospectively, which could introduce bias. Furthermore, the database did not record preoperative antibiotic use, although it was not routinely administered for uncomplicated cases unless there was a significant delay in surgery. In some instances, antibiotics were given at the discretion of the attending surgeon, but this was believed to have minimal impact on study outcomes.

To account for missing data, multiple imputation was employed to create datasets for markers of disease severity. The results from these imputed datasets were consistent with the complete case analysis, suggesting that missing data did not systematically affect the findings. One challenge in comparing studies on appendicitis outcomes is the lack of consensus on defining "complex" or "perforated" appendicitis. This study addressed the issue by conducting an additional analysis that combined intraoperative recognition of perforation (e.g., a hole in the appendix, purulent peritonitis, or localized abscess) and histopathologic findings of perforation. The results from this broader definition were similar to those from the primary analysis, reinforcing the generalizability of the findings.

In the subgroup analysis of children under 5 years old, the rate of histopathologic perforation was 57.8%. Although there was a no significant increase in the risk of perforation with moderate surgical delay in this group, it emphasizes the need for extra attention to children in this age category. The main findings suggest that surgical delay does not increase the risk of surgical complications, regardless of disease severity at the time of diagnosis. Previous studies (1)(2) that did not control for bias have shown that delayed appendectomy in children is safe, aligning with the current study's results. By adjusting for disease severity, this study strengthens the evidence supporting the safety of surgical delay.

In contrast, Bonadio et al. (25) suggested that delayed appendectomy in

children increases the risk of perforation. However, their study had strict inclusion criteria that may not be generalizable, especially given concerns over the use of CT in paediatric patients due to radiation exposure. Although their findings may be relevant for specific subgroups, they could not be confirmed in this study.

Adult studies, such as those by Ditillo et al. (12) and Teixeira et al. (6), have found no link between surgical delay and perforation risk, although an increased risk of surgical site infection with delay was noted. A British multicentre cohort study and meta-analysis found similar results in adults, indicating no elevated risk of perforation due to short surgical delays. This study's findings in children align with these adult studies, showing that surgical delay does not lead to an increased risk of perforation, regardless of its duration.

The results support the idea that the progression to perforation in acute appendicitis may be halted upon hospital admission. Factors such as fasting, fluid resuscitation, and appropriate analgesia may help mitigate inflammation and prevent perforation. Preoperative antibiotics, though not commonly administered in this study, may also play a role in slowing disease progression. This concept aligns with the potential for spontaneous resolution of non-perforated appendicitis and strategies for observing such cases rather than performing immediate surgery (28).

In conclusion, the study confirms that surgical delay in acute appendicitis in children is generally safe, with no increase in complications or perforation rates. Emphasizing preoperative management, including fluid resuscitation, analgesia, and selective use of antibiotics, can reduce the need for emergent surgery. The study further suggests that acute appendicitis in children may not necessarily require immediate surgical intervention and can be safely managed with proper preoperative care.

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