


# Impact of the Coronavirus (COVID-19) Pandemic on the Care of Pediatric Acute Appendicitis

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## Abstract

**Background:** Appendicitis is the most common abdominal surgical emergency in children. With the rise of the Coronavirus-19 pandemic, quarantine measures have been enforced to limit the viral transmission of this disease. The purpose of this study was to identify differences in the clinical presentation and outcomes of pediatric acute appendicitis during the Coronavirus-19 pandemic.

**Methods:** A single-institution retrospective assessment of all pediatric patients (<18 years old) with acute appendicitis from December 2019 to June 2020 was performed at a tertiary care children's hospital. Patients were divided into two groups: (1) the Pre-COVID group presented on or before March 15, 2020, and (2) the COVID group presented after March 15, 2020. Demographic, preoperative, and clinical outcomes data were analyzed.

**Results:** 45 patients were included with a median age of 13 years [IQR 9.9 - 16.2] and 35 males (78%). 28 patients were in the Pre-COVID group (62%) and 17 in the COVID group (38%). There were no differences in demographics or use of diagnostic imaging. The COVID group did have a significantly delayed presentation from symptom onset (36 vs 24 hours,  $P < .05$ ), higher Pediatric Appendicitis Scores (8 vs 6,  $P = .003$ ), and longer hospital stays (2.2 vs 1.3 days,  $P = .04$ ). There were no significant differences for rates of re-admission, re-operation, surgical site infection, perforation, or abscess formation.

**Conclusion:** During the Coronavirus-19 pandemic, the incidence of pediatric acute appendicitis was approximately 40% lower. These children presented in a delayed fashion with longer hospital stays. No differences were noted for postoperative complications.

## Keywords

pediatric surgery, appendicitis, coronavirus pandemic, COVID-19, surgical quality

## Key Takeaways

- Pediatric patients during the Coronavirus-19 pandemic presented differently in the following ways: less frequently, delayed timing, and increased likelihood of acute appendicitis.
- Despite these differences, there was no impact on postoperative complications.
- The social, psychological, and regulatory difficulties associated with the Coronavirus-19 pandemic may influence families' decisions to seek vital care for their children.

## Introduction

Appendicitis occurs when the vermiform appendix becomes inflamed, potentially progressing to an abscess,

perforation, ileus, peritonitis, and/or death. Appendicitis is the most common abdominal surgical emergency with an annual incidence of approximately 10 per 100,000 people in the United States.<sup>1</sup> Pediatric patients are particularly vulnerable, as the highest incidence occurs between 10-19 years of age.<sup>2</sup> While the incidence of appendicitis has

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stabilized in the United States, trends in management have begun to shift from appendectomies to antibiotics.<sup>3</sup> However, a recent study on pediatric acute uncomplicated appendicitis shows that the failure rate is greater for medical management than surgical management.<sup>1,4</sup> Surgical management will therefore likely serve as the primary treatment modality for pediatric acute appendicitis moving forward.

The Coronavirus-19 (COVID-19) pandemic has greatly influenced patients' use of and access to the health care system across all fields. While all patient groups have been impacted, pediatric patients are a particularly concerning cohort. Recent data shows a decline in the number of pediatric emergency department visits for all common, serious conditions with a 19% decrease for appendicitis.<sup>5</sup> This decline is worrisome since an associated delayed presentation may contribute to worse clinical outcomes. No major conclusions have been reached on this point, and conflicting findings were published before the COVID-19 pandemic for both adult and pediatric patients.<sup>6,7</sup> Nevertheless, earlier intervention should be achieved whenever possible to limit any potentially preventable adverse effects. The objective of this study was to assess the impact of the COVID-19 pandemic on the presentation and surgical management of pediatric acute appendicitis at a single institution in South Carolina.

## Methods

### *Patients and Design*

This study was approved by the Institutional Review Board (IRB# 00101804) at The Medical University of South Carolina (MUSC). A retrospective assessment of all pediatric patients (<18 years old) with a diagnosis of appendicitis between December 2019 and June 2020 was performed. Patients were identified using the International Classification of Diseases (ICD) 10 codes for acute appendicitis. Acute appendicitis was defined as a clinical and imaging diagnosis compatible with acute inflammation of the appendix. The pathological evaluation of the appendix was considered the gold standard. The patients were divided into two groups: (1) the pre-COVID group consisted of patients presenting on or before March 15, 2020, and (2) the COVID group included those presenting after March 15, 2020. This time division was based on the South Carolina Executive Order Number 2021-21 Stay-at-Home or Work Order implemented by the state as a response to the public health emergency.<sup>8</sup> Inclusion criteria consisted of patients with acute appendicitis that underwent either surgical or medical management. Exclusion criteria consisted of patients with other abdominal pain diagnoses, those treated outside of our main facility, and those presenting for an interval appendectomy.

Demographic, preoperative, and clinical outcomes data were extracted from each individual patient's chart. Demographic data included patient age, gender, primary language, and reported race. Preoperative data included time from reported symptom onset (SO) to Emergency Department (ED) arrival in hours, time from ED arrival to entering the operating room (OR) in hours, use of ultrasound imaging, use of computerized tomography (CT) imaging, Pediatric Appendicitis Score (PAS), and white blood cell (WBC) count. Demographic and preoperative data were assessed across the two groups as well as across those tested and not tested for COVID. Clinical outcomes data included the length of hospital stay (hLOS), incidence of perforation, re-admission, re-operation, superficial site infection (SSI), and abscess formation. All clinical outcomes were assessed within the first 30 days after initial surgical management.

### *Statistical Analysis*

Descriptive data is presented in tables and graphs. Variable analysis was determined based on the underlying distribution. For normally distributed variables, means with standard deviations are presented. For non-normally distributed variables, medians and interquartile ranges are presented. The Kruskal-Wallis test was used to compare continuous covariates between both groups while the Chi-squared or the Fisher's exact test was used to compare categorical variables. Data was analyzed using the R statistical software version 3.6.3 (R core Team 2015, Vienna, Austria).

## Results

45 patients met the inclusion criteria. 35 were male (78%) with a median age of 13 [9.9-16.2] years. 28 patients were in the Pre-COVID group (62%), and 17 patients were in the COVID group (38%). Corresponding demographic and preoperative characteristic data are summarized in [Table 1](#). No differences were found between the two groups for age, gender, primary language, and reported race. Most patients in both groups were teenagers, male, spoke English, and were white. With regards to preoperative characteristics, no differences were found between the two groups for time from ED to OR, use of ultrasound, use of CT, and WBC count. Most patients in both groups had ultrasound imaging, but less than half of both groups had CT imaging. The COVID group did demonstrate a significantly delayed presentation regarding the time from SO to ED (36 [24-72] hours vs 24 [12-24] hours,  $P$ -value = .049). The PAS was also significantly higher in the COVID group (8 [7.5-9] vs 6 [5-7],  $P$ -value = .003). No differences were identified between those tested and those not tested for COVID with respect to age, gender, and time from ED to OR (see [Table 2](#)).

**Table 1.** Demographic and Preoperative Characteristics of Pediatric Acute Appendicitis.

	Pre-COVID (n = 28, 62%)	COVID (n = 17, 38%)	P-value
<b>Age (years, IQR)</b>	13 [9-16]	13 [11-16]	.63
<b>Male gender (yes, %)</b>	21 (75)	14 (82)	.71
<b>Primary language – English (yes, %)</b>	26 (93)	15 (88)	.62
<b>Race – White (yes, %)</b>	17 (61)	13 (76)	.67
<b>Time from SO to ED (hours, IQR)</b>	24 [12-24]	36 [24-72]	<.05 <sup>a</sup>
<b>Time from ED to OR (hours, IQR)</b>	7 [3-14]	11 [7-14]	.38
<b>Use of ultrasound (yes, %)</b>	18 (64)	12 (71)	.75
<b>Use of CT (yes, %)</b>	12 (43)	8 (47)	1.00
<b>PAS (score, IQR)</b>	6 [5-7]	8 [7.5-9]	.003 <sup>a</sup>
<b>WBC count (cells x 10<sup>9</sup>, IQR)</b>	13.4 [9.7-15]	16.6 [12.1-18.9]	.07
<b>Perforation (yes, %)</b>	7 (25)	7 (41)	.10

Abbreviations: IQR, interquartile range; SO, symptom onset; ED, emergency department; OR, operating room; PAS, pediatric appendicitis score; WBC, white blood cell.

<sup>a</sup>Statistically significant.

**Table 2.** Clinical Outcomes of Pediatric Acute Appendicitis by COVID Testing.

	Tested (n = 10, 22%)	Not tested (n = 35, 78%)	P-value
<b>Age (years, IQR)</b>	13 [10-13]	14 [10-16]	.35
<b>Male gender (yes, %)</b>	9 (90)	26 (74)	.41
<b>Time from ED to OR (hours, IQR)</b>	6 [1-10]	4 [1-10]	.74

Abbreviations: IQR, interquartile range; ED, emergency department; OR, operating room.

The clinical outcomes data is summarized in [Table 3](#). No differences were identified for the rates of re-admission, re-operation, SSI, and abscess formation. One case of re-admission, re-operation, and abscess formation was identified in the COVID group, and one case of SSI was identified in the Pre-COVID group. The COVID group did have a significantly longer hLOS relative to the pre-COVID group ( $2.2 \pm 1.8$  days vs  $1.3 \pm 1.8$  days,  $P$ -value = .04).

## Discussion

The COVID-19 pandemic has greatly influenced how, when, and where health care is delivered in the United States. Pediatric patients are a uniquely vulnerable population during this time, as decisions to seek care are often not their own but instead dependent on their guardians. Acute appendicitis is a particular condition that has been studied considerably over the course of the pandemic for adults and adolescents both within the United States and abroad.<sup>9-30</sup> The study presented here is unique though in that it is the first to detail the surgical management of pediatric acute appendicitis in South Carolina during the COVID-19 pandemic. The findings suggest that pediatric patients present less frequently, with delayed timing, and increased likelihood of acute appendicitis relative to pre-pandemic patients. Nevertheless, surgical management

was effective with no worse postoperative complications but longer hospital stays.

The preoperative presentation of pediatric patients differed in several key areas across the COVID-19 pandemic. Although the demographic data did not differ in the pre-COVID and COVID groups, the rate of acute appendicitis decreased by approximately 40% (28 patients pre-COVID vs 17 patients COVID). The COVID group also had a significantly greater time from SO to ED arrival with a 50% longer median value (24 hours pre-COVID vs 36 hours COVID). Various other studies assessing pediatric acute appendicitis during the COVID-19 pandemic support both findings: a decrease in incidence and delay in presentation.<sup>13,14,17,26</sup> Several reasons may explain these trends. Common viral illnesses have been associated with appendicitis, and social distancing efforts may have limited the overall incidence of these potentially inciting viral illnesses.<sup>31-34</sup> Another thought is that the true incidence of appendicitis did not decrease but instead the anxiety and fear related to the COVID-19 pandemic may have influenced families' decisions to present to the ED or not. A unique finding presented here though is that the median time from ED to OR was not influenced by the administration of COVID tests. This result may encourage providers to universally administer COVID tests to pediatric patients in order to help reduce transmission of the disease.

**Table 3.** Clinical Outcomes of Pediatric Acute Appendicitis by COVID Era.

	Pre-COVID (n = 28, 62%)	COVID (n = 17, 38%)	P-value
<b>hLOS (days, SD)</b>	1.3 (1.8)	2.2 (1.8)	.04 <sup>a</sup>
<b>Re-admission (yes, %)</b>	0 (0)	1 (6)	.40
<b>Re-operation (yes, %)</b>	0 (0)	1 (6)	.40
<b>SSI (yes, %)</b>	1 (4)	0 (0)	1.00
<b>Abscess formation (yes, %)</b>	0 (0)	1 (6)	.40

Abbreviations: hLOS, hospital length of stay; SD, standard deviation; SSI, superficial site infection.

<sup>a</sup>Statistically significant.

The COVID group also had significantly higher median PAS values (6 pre-COVID vs 8 COVID). PAS is a well-validated, accurate tool for the early diagnosis of appendicitis in adolescents that relies on both subjective and objective data.<sup>35,36</sup> While no other studies have analyzed PAS during the COVID-19 pandemic, the PAS data in this study suggest a greater likelihood of appendicitis for patients presenting to the ED. In particular, the median value of 6 in the pre-COVID group corresponded to an equivocal score (ie, 4-6), whereas the median value of 8 in the COVID group corresponded to a high risk score (ie,  $\geq 7$ ). Although not statistically significant, the rate of perforation and WBC counts did trend as higher in the COVID group relative to the pre-COVID group (25% Pre-COVID vs 41% COVID,  $P$ -value = .10) (13.4 Pre-COVID vs 16.6 COVID,  $P$ -value = .07). Other pediatric studies have shown increases in perforation rates by anywhere from two to four times during the COVID-19 pandemic.<sup>10,13</sup> A larger sample size may have enabled a more thorough understanding of perforation and WBC counts in the study presented here. Overall, the preoperative findings are worrisome for both patients and providers, suggesting that adolescents are receiving care less frequently and with a higher likelihood of diagnosis during the COVID-19 pandemic.

The clinical outcomes of pediatric patients did not demonstrate as much variance across the COVID-19 pandemic as did the preoperative characteristics. No significant differences were noted with respect to re-admission, re-operation, SSI, and abscess formation after surgery. These findings align with several studies demonstrating no worse postoperative complications for pediatric acute appendicitis during the COVID-19 pandemic.<sup>12,14</sup> However, one other pediatric study identified worse outcomes.<sup>13</sup> This variance in findings requires that further validation be implemented to better understand and improve the clinical outcomes moving forward. The findings presented here though suggest that current surgical management is appropriate and that no major changes are needed from a care standpoint. A systematic review and meta-analysis assessing non-surgical management of acute appendicitis during the COVID-19 pandemic revealed that it failed more often in

adolescents.<sup>18</sup> However, it also revealed non-surgical management had significantly lower complication rates than surgical management.

The only clinical outcome that differed in the study presented here was the hLOS with the COVID group having an almost 70% longer stay (1.3 days pre-COVID vs 2.2 days COVID,  $P$ -value = .04). No specific changes were implemented with respect to the postoperative management of appendicitis. A potential reason for the longer hLOS in spite of no differences in postoperative complications relates to the strain on hospital staffing and resources during the COVID-19 pandemic. The COVID group was defined by those patients seen after the declaration of the South Carolina Stay at Home order, which ultimately corresponded to the most challenging time for the children's hospital. A recent multicenter study found similar results with no worse rates of perforation in their pediatric appendicitis population but significantly longer hLOS.<sup>37</sup> Another consideration is that the longer hLOS relates to the higher rates of perforation identified. Although the perforation rate was not statistically significant, it did trend towards higher in the COVID-19 group (25% Pre-COVID vs 41% COVID,  $P$ -value = .10). A larger sample size would have provided further power and perhaps revealed a significant association. Further validation is ultimately necessary to confirm this assertion.

This study has several limitations given its design as a retrospective analysis. First, the analysis was performed in a single institution across a six-month timeframe, thereby confining the total sample size. While significant associations were identified in this study, a larger sample size may have provided stronger validation of other associations that trended towards statistical significance. Second, the sample size was derived from a single state. The external validity is likely influenced by the varying social and regulatory approaches to the COVID-19 pandemic across individual states. Third, the preoperative assessment of patients was guided in part by subjective variables, such as patient-reported time from SO to ED and provider-reported PAS. While both were statistically significant with no identifiable confounders, a more objective approach would be desirable. Moving forward, further validation of the findings presented here is necessary with

larger, multi-center studies that span the entire country with a standardized approach.

In conclusion, this study is the first to assess the surgical management of pediatric acute appendicitis in South Carolina during the COVID-19 pandemic. The incidence of appendicitis decreased by approximately 40%; however, children presented in a delayed fashion with increased severity and longer hospital stays. Overall, the social, psychological, and regulatory difficulties associated with the COVID-19 pandemic may have influenced families' decisions to seek vital care for their children. The decreased incidence and delay in seeking care for a surgical emergency such as acute appendicitis may further suggest that less severe surgical and medical diseases face similar if not worse limitations in management. Although no differences were noted for clinical outcomes, families should be educated and encouraged to pursue early assessment of potentially emergent conditions such as acute appendicitis. Future studies should reconsider these findings and provide updates as the COVID-19 pandemic and its aftermath continue to unfold.

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