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Perforated Appendicitis During a Pandemic: The Downstream Effect of COVID-19 in Children

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ABSTRACT

Introduction: Coronavirus Disease-19 (COVID-19) was declared a pandemic in March 2020. States issued stay-at-home orders and hospitals cancelled non-emergent surgeries. During this time, we anecdotally noticed more admissions for perforated appendicitis. Therefore, we hypothesized that during the months following the COVID-19 pandemic declaration, more children were presenting with perforated appendicitis.

Materials and Methods: This is a retrospective cohort study reviewing pediatric patients admitted at a single institution with acute and/or perforated appendicitis between October 2019 to May 2020. Interval appendectomies were excluded. COVID-19 months were designated as March, April, and May 2020. Additional analysis of March, April, and May 2019 was performed for comparison purposes. Analyzed data included demographics, symptoms, white blood cell count, imaging findings, procedures performed, and perforation status. Statistical analysis was performed.

Results: During the study period, 285 patients were admitted with the diagnosis of acute appendicitis with 95 patients being perforated. We identified a significant increase in perforated appendicitis cases in the three COVID-19 months compared with the preceding five months (45.6% vs 26.4%; $P < 0.001$). In addition, a similar significant increase was identified when comparing to the same months a year prior ($P = 0.003$). No significant difference in duration of pain was identified ($P = 0.926$).

Conclusion: The COVID-19 pandemic and its associated stay-at-home orders have had downstream effects on healthcare. Our review has demonstrated a significant increase in the

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number of children presenting with perforated appendicitis following these stay-at-home ordinances. These results demonstrate that further investigations into the issues surrounding access to healthcare, especially during this pandemic, are warranted.

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Introduction

The presentation and continued evolution of the Coronavirus Disease 2019 (COVID-19) remains a public health priority. With varying symptoms and transmission rates, this disease has spread quickly, affecting millions of people worldwide.[1-3] As a result of climbing numbers and its global presence, the World Health Organization (WHO) declared COVID-19 as a pandemic on March 11, 2020[3]. Responses designed to diminish the effects of the virus varied around the world from strict person-to-person tracking to mask wearing mandates and much more. Without a vaccine, many countries took ownership closing their borders and instituting quarantine measures.

Similarly, the United States began promoting social distancing mandates, hoping to limit the spread of this novel disease. Many states issued restrictions on traveling, formal stay-at-home orders, and hospital systems began cancelling non-emergent surgeries. Social media and news outlets promoted the idea of "flattening the curve," referencing the number of available hospital beds and ventilators in each state[2,4]. Limiting the use of hospital resources, reducing the excessive use of personal protective equipment (PPE), and minimizing COVID-19 patient exposure became the goal for healthcare systems.

With these new measures in place, significant changes were noted within hospital systems, including decrease emergency room utilization and hospital census[5]. Following the declaration, we anecdotally noted that our pediatric surgery service was admitting more cases of perforated appendicitis. This change was similar to some institutions that reported a decrease in the number of appendectomies performed and others that promoted non-operative, medical management pathways[6,7]. Many papers have focused on the evolution of COVID-19, but only a few analyze the downstream effect it may have on other disease processes, like appendicitis. Therefore, we hypothesized that during the months following the COVID-19 pandemic declaration, more children were presenting with perforated appendicitis.

Materials and Methods

This is a retrospective cohort study reviewing all pediatric patients admitted at a single, large children's hospital with a diagnosis of acute and/or perforated appendicitis between October 2019 and May 2020. As this study involved protected health information, it was approved by our local institutional review board [University of Alabama at Birmingham (UAB) IRB]. The diagnosis of acute and/or perforated appendicitis was determined with a combination of physical exam, preoperative imaging, and/or intraoperative findings. Children that underwent interval appendectomies were excluded from this analysis. Medical records were reviewed to extract patient demographics, symptom durations, white blood cell count, imaging findings, procedures performed, and perforation status. If the patient underwent an appendectomy, the perforation status was confirmed with pathology. A gangrenous appendix or purulent fluid without an obvious gross perforation or pathologic finding of a perforation was considered acute appendicitis.

Pre-pandemic months were then compared with designated COVID-19 months. COVID-19 months were designated as March, April, and May 2020 as these three months followed the declaration of COVID-19 as a pandemic. In addition, these three months had the highest active stay-at-home orders in place in our region. For an additional comparison group, analysis was performed on a similar patient population for the months of March, April, and May 2019.

All variables were reviewed and descriptive statistical analysis performed. Univariable statistics between COVID-19 months and the five preceding months were generated with chi-square analysis. Similar univariable analysis was completed comparing the 2019 and 2020 months. Significance level was set at $P = 0.05$. Data were analyzed using SPSS version 25 (*IBM; Armonk, NY*). Study design and interpretation followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines[8].

Results

After excluding the interval appendectomies performed, there were a total of 285 patients admitted between October 2019 to May 2020 with the diagnosis of acute appendicitis with 95 patients identified as perforated appendicitis. The median age was 10.9 years (IQR: 8-13.5 years). Sixty percent were male. This group of 285 patients was further split for comparison purposes. Of those 285 patients, 150 were in the COVID-19 months cohort. Forty-seven patients in the COVID-19 group had perforated appendicitis. Similar demographics were identified for the other comparison group (March, April, and May of 2019), where a total 102 patients were admitted with acute appendicitis with 26 perforations. Please see Table 1 for detailed demographics of each group.

All patients underwent imaging with 24.5% receiving ultrasounds and 75.5% having a CT scan. Many of these CT scans were performed at other institutions and reinterpreted at our tertiary medical center. White blood cell counts (WBC) were reviewed for all patients admitted for appendicitis. The median white blood cell count was 16.9 before the declared COVID-19 months (IQR 12.7-19.0, units: $10^3/\mu L$). During the COVID-19 months, the median WBC was 17.0 (IQR 13.0-20.1; $P=0.75$). Lastly, the median WBC in the March-May 2019 was 15 (IQR 12-17.5; $P=0.40$). In addition to labs and imaging, the patient's duration of pain was reviewed. There was no signifi-

Table 1 – Basic demographics.

	Oct 2019-Feb 2020 (5-months prior)	March-May 2020 (COVID-19 Months)	March-May 2019 (1-year prior)
Patients with Appendicitis	182	103	102
Perforated Appendicitis Diagnosis	48 (26.4%)	47 (45.6%)	26 (25.5%)
Age [IQR]	10.1 [8.0-13.3]	11.6 [8.4-14.3]	10.7 [7.9-13.0]
Number of Males (%)	142 (78%)	63 (61%)	64 (63%)
Number of Females (%)	40 (22%)	40 (49%)	38 (37%)
Private Insurance (Perforated)	21	22	8
Medicaid or Self Pay (Perforated)	26	25	18

Table 2 – Outcomes compared by groups.

	Oct 2019-Feb 2020 (5-months prior)	March-May 2020 (COVID-19 Months)	March-May 2019 (1-year prior)
WBC (median)	16.9 [$P = 0.75$]	17.0	15.0 [$P = 0.40$]
Perforations	48 (26.4%) [$P < 0.001$]*	47 (45.6%)	26 (25.5%) [$P = 0.003$]*
IR Intervention	12 [$P = 0.86$]	11	10 [$P = 0.17$]
Home Antibiotics	5 [$P = 0.75$]	4	1 [$P = 0.44$]
Readmission	6 [$P = 0.17$]	11	6 [$P = 0.97$]

* indicates significant value

cant different in duration of pain when comparing our groups (median = 2 days; IQR 1-3; P=0.926).

Univariate analysis was performed to evaluate perforation status. The first comparison was between the three COVID-19 months and the preceding five months before the declaration of a pandemic. We identified a significant increase in the number of perforated appendicitis admissions to the pediatric surgery service (45.6% vs. 26.4%; P<0.001). A similar finding was found when comparing data to the months of March – May 2019, a year prior to the pandemic. The perforated appendicitis rate during those months of 2019 was 25.5%, significantly lower than the COVID-19 months perforation rate (45.6%, P=0.003). Lastly, readmission rates, interventional radiology (IR) procedures for abscess drainage, and discharges with home IV antibiotics were all similar among the groups ($P > 0.05$) All comparisons can be seen in Table 2.

Discussion

Acute appendicitis remains a common indication for surgery in the pediatric population. Techniques have evolved from traditional open approaches to various laparoscopic techniques, and even non-operative pathways are being offered to select patients[6,9]. Typically, a combination of labs, imaging, symptoms, and perforation status helps dictate the treatment pathway. Some predictive factors for perforated appendicitis include pain longer than two days' duration, fever, elevated C-reactive protein level, and presence of an appendicolith[10]. Delays in presentation may affect those predictive factors, primarily the duration of pain. Following the WHO declaration of a pandemic, strict stay-at-home orders were instituted and an overwhelming sense of fear ensued[4]. With these new sets of challenges, concerns arose about delays in presentation to the hospital contributing to more advanced disease.

Specifically, for appendicitis, a delay in presentation has been linked to perforation[10]. When comparing the months preceding the COVID-19 pandemic declaration, our data showed a significant increase in the number patients presenting and being treated for perforated appendicitis. A previous study by Gerall, *et al.* had also identified delayed presentations and suboptimal outcomes for pediatric acute appendicitis during this pandemic[11]. Their comparison group was limited to the same time period in a previous year. Acute appendicitis is known to have seasonal and geographical differences[12,13]. Therefore, we compared our pandemic months with several months pre-pandemic as well as the same period the year prior to eliminate these confounders.

Similarly, we reviewed duration of symptoms and white blood cell counts. No significant difference was noted between these variables, highlighting the inconsistency with patient histories that may be encountered with children. As we identified a higher perforation rate during the COVID-19 months, we still believe this relates to a delay in care, which likely was associated with a longer duration of pain not recognized by patients' families. Staying home was high on families' priority lists. This new fear and anxiety of leaving home potentially contributed the overall perforation rate[14]. Fortunately, we did not identify increased needs for IR intervention, readmission rates, or discharges on home antibiotics among our groups.

Another downstream effect caused by the pandemic is the concern for multisystem inflammatory syndrome (MIS-C) that follows COVID-19 infection. These patients may share similar symptoms with appendicitis, including fever and abdominal pain[15,16]. Testing was still limited at our institution during these early months of the pandemic. Therefore, screening for COVID-19 in all of our patients was not performed. For this reason, we do not know the COVID-19 positivity rate in our pa-

tient population and cannot comment on if MIS-C contributed to outcomes in our patients. It will be important to investigate the incidence of MIS-C in children undergoing evaluation for acute appendicitis during this past year and the near future.

We recognize several limitations with our study. The primary limitation is inherent to the study design as a retrospective, single institution study. Physician treatment algorithms at other institutions may differ. However, we believe our results can still be generalized to similar large pediatric centers as referral patterns are similar and patient demographics are likely comparable. We acknowledge several potential confounding variables that could affect the generalizability of the study. For instance, stay-at-home orders varied from state to state. Milder mandates or areas of stricter enforcement likely had different effects on individuals' willingness to seek hospital care. Another limitation includes the travel restrictions that may have altered our hospital's typical catchment radius. As a large, tertiary care center, our patient population encompasses patients from neighboring counties and even states. Some centers that traditionally treat appendicitis in children may have had limited resources due to COVID-19 cases, thus forcing a transfer and potential delay in care. Of note, our state did not limit out-of-state visitors, potentially mitigating the effect on hospital transfers. Lastly, physician bias on limiting hospital admissions for appendicitis to keep beds open for potential COVID-19 patients could have affected the results. During these initial months of the pandemic, our hospital had a low patient census, meaning admission restrictions were not needed.

Conclusion

COVID-19 has had a significant impact on the way we have lived over the past year. Mask wearing has become the new normal. Travel restrictions remain in place. Hospitals continue to deal with the potential of becoming overcrowded with the disease. In addition, COVID-19 has had effects on other disease processes, more specifically, acute appendicitis. We have demonstrated a significant increase in the number of children presenting with perforated appendicitis following the declaration of a COVID-19 as a pandemic and the subsequent implementation of statewide stay-at-home orders. Reluctance to seek care due to fear of COVID-19 exposure is a concern. Delays in care may result in more severe forms of the illness, in our case, perforation of the appendix. Further investigation into the issues surrounding access to healthcare, especially during this pandemic, are warranted to ensure adequate care for everyone.

Author Contributions

RR, MC, EB, and JE helped with initial idea and development of this study. JE was involved with collecting the data. JE and MM performed the statistical analysis. SA, CM, DR, and VM helped with interpretation of data, table creations, and further data analysis. JE, DR, EB, and MC assisted in manuscript writing. All authors helped with several revisions and final manuscript production.

Disclosure

All authors have nothing to disclose. Dr. Martin is an Associate Editor for the Journal of Surgical Research; as such, he was excluded from the entire peer-review and editorial process for this manuscript.

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