


# Acute Appendicitis During The COVID-19 Pandemic: A Multicenter, Retrospective Analysis From The US Epicenter

The American Surgeon  
2022, Vol. 0(0) 1–9  
© The Author(s) 2022  
Article reuse guidelines:  
[sagepub.com/journals-permissions](https://sagepub.com/journals-permissions)  
DOI: 10.1177/00031348221103649  
[journals.sagepub.com/home/asu](https://journals.sagepub.com/home/asu)  


Richard Tamirian, BS<sup>1</sup>, Michael Klein, MD<sup>1,2</sup>, Patricia Chui, MD, PhD<sup>1,2</sup>, Julia Park, MD<sup>1,2</sup>, Spiros Frangos, MD, MPH<sup>1,2</sup>, Paresh Shah, MD<sup>1</sup>, and Cris M.K. Malino, MD, MPH<sup>1</sup>

## Abstract

**Background:** Acute appendicitis (AA) is the most common surgical emergency, with a relatively stable yearly incidence. During the first wave of the COVID-19 pandemic, as New York City (NYC) emerged as the US epicenter, hospitals saw a marked reduction in patients presenting with non-COVID-related diseases. The objective of this study was to characterize the effects of the pandemic on the incidence, presentation, and management of AA.

**Methods:** A retrospective analysis of patients with AA who presented to two academic medical centers during the NYC COVID peak (March 22nd-May 31st, 2020) was performed. This group was compared to a control cohort presenting during the same period in 2019. Primary outcomes included the incidence of AA, complicated disease, and management. Secondary outcomes included duration of symptoms, hospital length of stay, and complication rates. Statistical analyses were performed using Mann-Whitney U, Chi-square, and Fisher's exact tests.

**Results:** A 49.1% reduction in the incidence of AA was seen between 2019 (n = 114) and 2020 (n = 58). Median duration of symptoms doubled from 1 day in 2019 to 2 days in 2020 ( $P < .02$ ). Proportionally, the incidence of complicated appendicitis rose from 19.3% to 41.4% ( $P < .005$ ). 32.4% of patients with uncomplicated AA underwent non-operative management in 2020, compared to 12% in 2019 ( $P < .02$ ). Hospital length of stay and complication rates were similar between years.

**Discussion:** Significantly fewer AA patients presented during the initial phase of the pandemic. Patients presented later, which may have contributed to a higher proportion of complicated disease. Surgeons were also more likely to treat uncomplicated AA nonoperatively than they were prior. Further research is needed to understand the long-term consequences of these changes.

## Keywords

appendicitis, appendectomy, COVID-19, emergency general surgery, acute care surgery

## Key Takeaways

- Significantly fewer patients with acute appendicitis presented to our hospitals during the initial phase of the COVID-19 pandemic, with a proportional increase in complicated appendicitis from 19.3% in 2019 to 41.4% in 2020.
- A larger proportion of patients presented after a longer duration of symptoms, which may have contributed to a higher proportion of complicated disease.
- Surgeons were also more likely to treat uncomplicated acute appendicitis nonoperatively than they were prior to the pandemic.

## Introduction

The World Health Organization declared Coronavirus Disease 2019 (COVID-19) a worldwide pandemic on

---

<sup>1</sup>Department of Surgery, New York University Grossman School of Medicine, New York, NY, USA

<sup>2</sup>Department of Surgery, New York City Health + Hospitals/Bellevue, New York, NY, USA

### Corresponding Author:

Richard Tamirian, Department of Surgery, NYU Grossman School of Medicine, 334 E. 26th Street New York, NY 10010, USA.  
Email: [richard.tamirian@nyulangone.org](mailto:richard.tamirian@nyulangone.org)

March 11th, 2020. On March 22nd, as New York City (NYC) emerged as the epicenter of disease outbreak in the United States and a first wave of COVID-19 patients flooded its many hospitals, New York State issued a “New York State on Pause” executive order, closing all non-essential businesses, banning social gathering, and ordering residents to shelter in place. To conserve resources for the expected large influx of COVID-19 patients, hospitals around the city also postponed or canceled elective procedures.<sup>1</sup> Health systems across the city also began to see a marked reduction in patients presenting with non-COVID-related urgent and emergent conditions such as acute coronary syndrome, stroke, and acute abdomen.<sup>2-4</sup>

Acute appendicitis (AA) is the most common surgical emergency worldwide, and appendectomy is the gold standard treatment for acute, uncomplicated disease.<sup>5</sup> A study of surgeries performed in Taiwan during the SARS-CoV-1 outbreak in 2003 identified appendectomy as the procedure with the lowest demand elasticity, with the number of appendectomies performed being generally insulated from societal and pandemic-related changes.<sup>6</sup> Given the expected steady incidence of AA, surgeons in NYC expected continued influx of this common surgical disease.

However, despite these expectations, the number of patients presenting with AA in New York City declined dramatically. Hospitals nationwide saw a 42% decrease in emergency department (ED) visits in March and April 2020, with the largest decline in visits for complaints of abdominal pain.<sup>4</sup> Multiple recent studies have shown declines in patients presenting with AA, delays in patients seeking treatment, and a marked decrease in appendectomies performed worldwide during the COVID-19 pandemic.<sup>7-10</sup>

The objective of this study is to characterize the effect of the COVID-19 pandemic on the incidence, presentation, complications, and management of AA in two large, academic hospitals in New York City. NYU Tisch Hospital, part of NYU Langone Health, is a private, non-profit, 1100-bed teaching hospital. New York City Health + Hospitals/Bellevue is the flagship of the largest municipal hospital system in the United States, and is a public, 1500-bed teaching, safety-net hospital and Level I trauma center. Surgical staff at both hospitals followed administrative guidance throughout the pandemic to continue emergency surgery as necessary.<sup>1</sup> In comparison to 2019, we hypothesize there was a significant decrease in the incidence of acute appendicitis and an increase in the proportion of patients presenting with perforation or more complicated disease.

## Materials and Methods

This retrospective cohort study was approved by the NYU Grossman School of Medicine Institutional Review Board and the Bellevue Research Review Committee.

All eligible patients were identified using the electronic medical record reports of general surgery consults billed and by using International Classification of Disease 10 (ICD-10) codes. Patients 18 years or older with a diagnosis of AA, who presented between March 22nd and May 31st, 2020 comprised the pandemic cohort. A control cohort consisted of patients with AA presenting during the same period in 2019.

The primary outcomes were the differences in the incidence of AA, incidence of complicated and uncomplicated disease, and operative and non-operative management between the cohorts. Complicated appendicitis was defined as AA with radiographic or intra-operative findings consistent with abscess, phlegmon, or perforation.

Secondary outcomes included duration of symptoms prior to presentation, patient referral patterns (eg, referred from urgent care, primary care, etc.), hospital length of stay (HLOS), 30-day complication rates, and rates of recurrence. Additional variables including demographics and medical comorbidities were also collected.

Statistical analysis was performed using R Studio software (RStudio, Boston, MA). Descriptive statistics were performed for all continuous variables and are reported as mean and standard deviation or median. Continuous variables were compared using Student's t-test or the Mann-Whitney U test. Categorical variables were compared using Fisher's exact test or the chi-square test. Significance was set at  $P < .05$ .

## Results

### Overall Incidence

172 patients were diagnosed with AA during the study period. 58 patients presented with AA during the pandemic period compared to 114 patients during the same period in 2019. This represented a 49.1% reduction.

### Demographics and Comorbidities

Patient demographic information and medical comorbidities are listed in [Table 1](#). There was no significant difference between the pandemic and control cohorts with regard to age, sex, race, or ethnicity. Five patients (8.6%) in 2020 had a positive COVID-19 PCR test. No patient tested positive for COVID-19 in the 30 days following their initial admission.

### Pre-Hospital Characteristics

The median duration of symptoms prior to presentation in 2020 was 2 days, compared to 1 day in 2019 ( $P = .0117$ ). Twenty-one patients (36.2%) in the pandemic cohort presented greater than 48 hours after the initial onset of

**Table 1.** Patient Demographics, Comorbidities, and Pre-Hospital Characteristics.

	Control cohort (n = 114)	Pandemic cohort (n = 58)	P value
Bellevue Hospital n (%)	25 (21.9)	14 (24.1)	
NYU Tisch Hospital n (%)	89 (78.1)	44 (75.9)	
Age (sd)	39.9 (15.9)	41.8 (17.4)	.5729
Median age	35	36	
Female, n (%)	58 (50.9)	27 (46.6)	.7076
Race			.6158
White, n (%)	65 (57.0)	30 (51.7)	
Black, n (%)	12 (10.5)	3 (5.2)	
Asian, n (%)	10 (8.8)	7 (12.1)	
Native Hawaiian/Pacific Islander, n (%)	1 (.9)	0 (.0)	
Other/Unspecified, n (%)	26 (22.8)	18 (31.0)	
Ethnicity			.8360
Hispanic or Latino, n (%)	21 (18.4)	13 (22.4)	
Not hispanic or Latino, n (%)	87 (76.3)	42 (72.4)	
Other/Unspecified, n (%)	6 (5.3)	3 (5.2)	
Positive COVID PCR, n (%)	0 (.0)	5 (8.6)	
Comorbidities			
Hypertension, n (%)	17 (14.9)	6 (10.3)	.4833
Hyperlipidemia, n (%)	11 (9.6)	9 (15.5)	.3152
Asthma, n (%)	11 (9.6)	9 (15.5)	.3152
Diabetes, n (%)	5 (4.4)	0 (.0)	.1689
Obesity, n (%)	7 (6.1)	4 (6.9)	1
Pre-hospital characteristics			
Median duration (d) of symptoms prior to presentation	1	2	.0117
Presentation >48 hours from symptom onset, n (%)	18 (15.8)	21 (36.2)	.0018
Referred from OSH, UC, or other provider, n (%)	42 (36.8)	14 (24.1)	.0928

sd = Standard Deviation; d = Days; PCR = Polymerase Chain Reaction; OSH = Outside Hospital; UC = Urgent Care.

symptoms, whereas 18 patients (15.8%) presented after that amount of time in 2019 ( $P = .0018$ ). Patients referred from an outside hospital, urgent care, or other provider comprised 24.1% of the pandemic cohort and 36.8% of the control cohort, though this was not significant ( $P = .0928$ ) (Table 1).

### Diagnosis and Severity of Disease

There was an increase in the proportion of patients presenting with complicated appendicitis during the pandemic. Twenty-four patients (41.4%) of the pandemic cohort were diagnosed with complicated disease, compared to 22 patients (19.3%) in 2019 ( $P = .0036$ ) (Figure 1). Thirteen patients (22.4%) in 2020 and 10 patients (8.8%) in 2019 were found to have either radiographic evidence or intra-operative findings of an intra-abdominal abscess ( $P = .0177$ ). Analysis of surgical specimens of 3 patients in the pandemic cohort and 2 patients in the control cohort revealed pathology consistent with appendiceal neoplasm ( $P = .3324$ ) (Table 2).

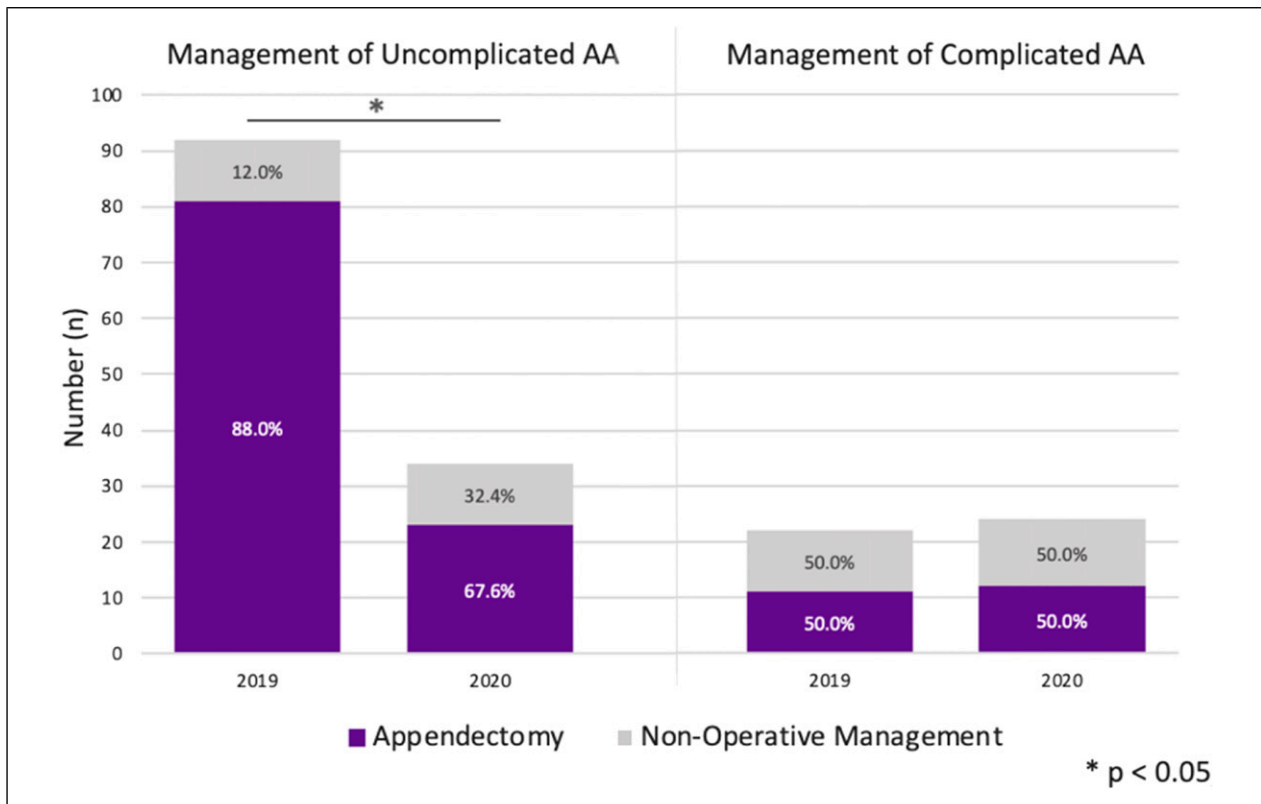
Patients presenting in 2020 with a diagnosis of complicated appendicitis had a longer median duration of

symptoms than those with uncomplicated disease (3 days vs 1 day,  $P = .0180$ ) (Table 3).

### Management

There was an increase in the proportion of patients managed non-operatively in the pandemic cohort. Twenty-three patients (39.7%) underwent non-operative management (NOM) during the pandemic compared to 22 patients (19.3%) in 2019 ( $P = .0072$ ) (Table 2). This difference was largely driven by an increase in the non-operative management of patients with uncomplicated AA. Of the 34 patients with uncomplicated AA in 2020, 11 (32.4%) underwent NOM. This represents a proportional increase from 2019 where 11 of 92 patients (12.0%) with uncomplicated disease underwent NOM ( $P = .0158$ ). There were no significant differences in the management of complicated AA between cohorts (Figure 1).

Five patients otherwise meeting eligibility for appendectomy were deferred due to COVID-19 pandemic-related restrictions, as documented in the medical record. Three of these patients had a positive COVID-19



**Figure 1.** Comparison of diagnosis and management of complicated and uncomplicated acute appendicitis (AA) during the study period.

PCR test. Additionally, one asymptomatic patient who was found to be COVID positive underwent laparoscopic appendectomy.

### Hospital Course, Complications, and Outcomes

Hospital length of stay was similar for both cohorts at 30 hours in 2020 and 32 hours in 2019 ( $P = .2798$ ) (Table 2). Patients managed non-operatively in 2020 had a longer median HLOS than those managed surgically, though this difference was not significant (48 hours vs 30 hours,  $P = .9864$ ). For patients with complicated AA, median HLOS was significantly shorter in the pandemic cohort at 48 hours than in the control cohort at 84 hours ( $P = .0298$ ). There was no significant difference in HLOS for uncomplicated appendicitis between 2019 and 2020.

There was no significant difference in 30-day complication rates between the pandemic and control cohorts. Eight patients (13.8%) in 2020 and eight patients (7.0%) in 2019 experienced at least 1 complication within 30 days of their initial presentation. Ileus was more common in the pandemic cohort, complicating 4 cases (6.9%) compared to 1 case in 2019 ( $P = .0448$ ). Three (13.0%) of the 23 patients managed non-operatively in 2020 presented with recurrence of appendicitis within 6 months of their initial

episode. Similarly, 3 of the 22 patients (13.6%) managed non-operatively in 2019 presented with recurrence (Table 2).

For patients presenting with uncomplicated appendicitis, there were no significant differences in HLOS, 30-day complication rates, or recurrence rates between those managed operatively or non-operatively.

Compared with patients managed operatively in 2020, the 5 patients whose operations were deferred due to COVID-19 infection or pandemic restrictions had similar HLOS and 30-day complication rates. One patient presented with recurrence within 6 months requiring operation. Three other patients underwent interval appendectomy within 6 months.

### Private versus Public Hospital

44 patients presented with AA to NYU Tisch Hospital, a private hospital, during the pandemic period. Fourteen patients presented to New York City Health + Hospitals/Bellevue, a public hospital. It is important to note that these two institutions are staffed by surgeons, all of whom hold faculty positions at NYU Langone Health. These surgeons followed the same evolving administrative and surgical guidelines during the pandemic period.

**Table 2.** Diagnosis, Management, and Outcomes.

	Control cohort (n = 114)	Pandemic cohort (n = 58)	P value
<b>Acute appendicitis</b>			
Uncomplicated, n (%)	92 (80.7)	34 (58.6)	.0036
Complicated, n (%)	22 (19.3)	24 (41.4)	
Intra-abdominal abscess, n (%)	10 (8.8)	13 (22.4)	.0177
Appendicolith, n (%)	27 (23.7)	18 (31.0)	.3594
Appendiceal neoplasm, n (%)	2 (1.8)	3 (5.2)	.3324
<b>Management</b>			
Operative, n (%)	92 (80.7)	35 (60.3)	.0072
Non-operative, n (%)	22 (19.3)	23 (39.7)	
Drainage by IR, n (%)	1 (.9)	3 (5.2)	.112
<b>Outcomes</b>			
Median hospital length of stay (hr)	32	30	.2798
Recurrence within 6 months, n (% of non-operative)	3 (13.6)	3 (13.0)	1
<b>Complications</b>			
Any complication within 30 days, n (%)	8 (7.0)	8 (13.8)	.1701
Aborted surgical dissection	2 (1.8)	0 (.0)	.5504
Intra-operative complication	1 (.9)	0 (.0)	1
Post-operative fever	3 (2.6)	0 (.0)	.5517
Intraabdominal abscess post-intervention	0 (.0)	2 (3.4)	.1124
Ileus during hospital stay	1 (.9)	4 (6.9)	.0448
New <i>C. difficile</i> infection	0 (.0)	1 (1.7)	.3372
Readmission for related within 30 days	2 (1.8)	3 (5.2)	.3368

IR = Interventional Radiology; hr = Hours; d = Days.

For the pandemic cohort, the median HLOS of 27 hours at NYU Tisch was significantly shorter than the median HLOS of 48 hours at Bellevue ( $P = .0243$ ). When examining each institution alone, the median HLOS at NYU Tisch decreased from 32 hours in 2019 to 27 hours in 2020 ( $P = .0378$ ). In contrast, HLOS at Bellevue increased from 32 hours in 2019 to 48 hours in 2020, though this difference was not significant ( $P = .2006$ ) (Table 4).

There was no significant difference in severity of disease, management, or complication rates between the two institutions in 2019 or 2020. However, each institution saw an increase in the proportion of patients presenting with complicated appendicitis during the pandemic. This was a statistically significant increase at Bellevue (12.0% vs 50.0%,  $P = .0190$ ), but was not at NYU Tisch Hospital (21.3% vs 38.6%,  $P = .0560$ ) (Table 4).

In 2020, the majority of patients (69%) identifying as Black or Hispanic sought care for their AA at Bellevue, whereas all patients identifying as White presented to NYU Tisch ( $P < .0001$ ). Additionally, 32.7% of White patients compared to only 6.3% of Black or Hispanic patients were referred to the emergency department from another facility such as an urgent care or primary care physician, though this difference was not significant ( $P = .0670$ ). Forty-four percent of Black or Hispanic patients

had evidence of complicated disease compared to 28.6% of White patients. However, this difference was also not significant ( $P = .4894$ ). Three Black or Hispanic patients (18.8%) underwent drainage of an appendiceal abscess by interventional radiology (IR), whereas no White patients required drainage ( $P = .0420$ ). Hospital length of stay was also significantly longer for patients identifying as Black or Hispanic at 2 days compared to 1 day for patients identifying as White. These differences were not present in 2019.

## Discussion

The COVID-19 pandemic changed the landscape of healthcare across New York City, with health systems seeing marked reductions in patients with non-COVID-related urgent and emergent conditions.<sup>2,3</sup> Our results are consistent with this phenomenon, showing a 49.1% decrease in the incidence of AA across our two institutions. This is in direct contrast to findings by Tsao et al which purported AA during the first SARS outbreak in 2003 as the condition with the lowest demand elasticity for treatment. This decrease in patients with AA presenting to our emergency departments in 2020 echoes observations from around the world showing similarly striking declines.<sup>7-12</sup> We hypothesize that this decrease in incidence represents the effects of patients' fears of the emergency

**Table 3.** Comparison of Uncomplicated and Complicated Appendicitis during the COVID-19 Pandemic (2020).

	Uncomplicated appendicitis (n = 34)	Complicated appendicitis (n = 24)	P value
Age (sd)	39.2 (17.3)	45.6 (17.3)	.1020
Female, n (%)	17 (50.0)	10 (41.7)	.7193
Race			.0148
White, n (%)	22 (64.7)	8 (33.3)	
Black, n (%)	1 (2.9)	2 (8.3)	
Asian, n (%)	1 (2.9)	6 (25.0)	
Native Hawaiian/Pacific Islander, n (%)	0 (.0)	0 (.0)	
Other/Unspecified, n (%)	10 (29.4)	8 (33.3)	
Ethnicity			1
Hispanic or Latino, n (%)	8 (23.5)	5 (20.8)	
Not hispanic or Latino, n (%)	24 (70.6)	18 (75.0)	
Other/Unspecified, n (%)	2 (5.9)	1 (4.2)	
Median duration (d) of symptoms prior to presentation	1	3	.0180
Appendiceal neoplasm, n (%)	0 (.0)	3 (12.5)	.0459
Median hospital length of stay (hr)	24	48	.0090
Any complication within 30 days, n (%)	2 (5.9)	6 (25.0)	.0554

sd = Standard deviation; hr = Hours; d = Days.

room, self-treatment, temporary emigration from NYC, and changes in the movement of individuals due to shelter-in-place orders.

In the weeks after the shelter-in-place orders were given, public service announcements took to the air, urging patients to seek timely management of their urgent conditions, as reports of patients delaying care emerged.<sup>13-15</sup> Our study supports the need for this type of outreach, as patients clearly delayed presentation by approximately 1 day. This delay may be explained by patients' fears of emergency departments, decreased access to healthcare due to pandemic restrictions, lack of transportation, or another factor yet to be established. With urban emigration during the surge, an increase in AA at suburban and rural hospitals was expected but has yet to be noted in the literature.<sup>16</sup>

Regardless of their cause, delays in presentation of AA pose the threat of increased frequency of perforation, increased morbidity, and increased mortality.<sup>17,18</sup> Our findings demonstrate a proportional increase of 22.1% in the incidence of complicated appendicitis during the pandemic. These results corroborate those of other studies in the US and around the world showing increases in rates of perforation and complicated disease during the pandemic.<sup>9,19-21</sup> Fortunately, no differences in the 30-day complication rates of either period were noted. However, perforation itself represents a significant complication: it may preclude early definitive management, prolong hospitalizations, and perhaps miss significant pathology, such as malignancy.

Our findings contrast those of Neufeld et al which showed a decrease in presentations of uncomplicated AA, without a significant change in the presentation of complicated AA. The authors suggest their findings may be due to spontaneous resolution of AA without treatment. While we acknowledge this possibility, a reliable method of predicting which patients will resolve without treatment and who will progress to perforation, sepsis, or death remains elusive.

Among our most significant findings, the management of patients during the pandemic changed significantly. This is consistent with multiple other studies showing a decrease in appendectomies performed worldwide.<sup>7,9,22</sup> This decrease may represent changes in hospital policies to conserve resources and limit exposure, patient or surgeon preferences, or our limited understanding of the risks of anesthesia and surgery in COVID patients at that time. Notably, none of our patients at either hospital developed COVID-19 within 30 days of admission. Our study also shows that this change in management did not result in subsequent increases in complication rates or hospital lengths of stay. These significant findings may help inform the management of AA in this and future pandemics when resources and personnel are strained.

To our knowledge, this is the first study to compare presentations and management of AA between private and public institutions within the same municipality. This comparison allowed us to highlight differences between the populations served by these two institutions. It has been established that individuals identifying as Black,

**Table 4.** Comparison of Private and Public Hospitals during the COVID-19 Pandemic.

	NYU Tisch Hospital		Bellevue Hospital		P value for comparison of hospitals in 2020
	2019 (n = 89)	2020 (n = 44)	2019 (n = 25)	2020 (n = 14)	
Age (sd)	40.5 (15.7)	42.1 (17.7)	37.7 (16.8)	41.1 (17.2)	.8636
Female, n (%)	45 (50.6)	22 (50.0)	13 (52.0)	5 (35.7)	.3784
Race					<.0001
White, n (%)	60 (67.4)	29 (65.9)	5 (20.0)	1 (7.1)	
Black, n (%)	11 (12.4)	2 (4.5)	1 (4.0)	1 (7.1)	
Asian, n (%)	6 (6.7)	6 (13.6)	4 (16.0)	1 (7.1)	
Native Hawaiian/Pacific Islander, n (%)	0 (.0)	0 (.0)	1 (4.0)	0 (.0)	
Other/Unspecified, n (%)	12 (13.5)	7 (15.9)	14 (56.0)	11 (78.6)	
Ethnicity					<.0001
Hispanic or Latino, n (%)	10 (11.2)	3 (6.8)	11 (44.0)	10 (71.4)	
Not hispanic or Latino, n (%)	75 (84.3)	39 (88.6)	12 (48.0)	3 (21.4)	
Other/Unspecified, n (%)	4 (4.5)	2 (4.5)	2 (8.0)	1 (7.1)	
Acute appendicitis					.5393
Uncomplicated, n (%)	70 (78.7)	27 (61.4)	22 (88.0)†	7 (50.0)†	
Complicated, n (%)	19 (21.3)	17 (38.6)	3 (12.0)†	7 (50.0)†	
Management					.1303
Operative, n (%)	70 (78.7)‡	24 (54.5)‡	22 (88.0)	11 (78.6)	
Non-operative, n (%)	19 (21.3)‡	20 (45.5)‡	3 (12.0)	3 (21.4)	
Outcomes					
Median hospital length of stay (hr)	32*	27*	32	48	.0243
Recurrence within 6 months, n (% of non-operative)	3 (15.8)	3 (15.0)	0 (.0)	0 (.0)	.5708
Any complication within 30 days	5 (5.6)	5 (11.4)	3 (12.0)	3 (21.4)	.3850

hr = Hours; † P = .0190, ‡ P = .0075, \* P = .0378.

Hispanic, and other historically marginalized populations were disproportionately affected by COVID-19.<sup>23,24</sup> Our results provide some evidence that this disparity extended beyond increased rates and severity of COVID infections. The differences in referral patterns to our emergency departments between Black or Hispanic and White patients may suggest differences in access to care, especially during pandemic conditions. Nonetheless, it highlights the role of the public institution as the primary source of care for many of these patients. Though we did not detect a significant difference between rates of complicated AA between these populations, longer hospital lengths of stay and increased referrals for IR drainage may suggest more severe disease in the Black or Hispanic populations. Further multi-institutional research is warranted to assess the widespread effects of COVID-19 on these and other minority groups, and the reasons for these differences.

There are several limitations of our study. We used billing records of general surgery consults and ICD-10 codes to identify patients within each cohort. It is possible some patients presenting with AA were not identified by these methods. Though the surgeons that comprise the faculty of the two represented hospitals are all faculty at

the same institution, there was no universal management guideline for uncomplicated appendicitis, nor complicated appendicitis. Therefore, there may have been undetected differences in the severity of disease or presentation for those who were managed surgically. Additionally, we also chose to record complications within 30 days of the patients' presentations. This may have excluded late occurring complications. Complication rates may also be underestimated during the pandemic period if patients are delaying or not seeking care due to the pandemic.

In conclusion, this study demonstrated a decrease in the incidence of acute appendicitis after the institution of the "New York State on PAUSE" executive order. Significant delays in presentation and increases in complicated disease represent both threats to patient health, as well as challenges that health systems must overcome in this and future infectious disease outbreaks. Additional research on the long-term effects of changes in management during the pandemic is needed. Further studies of the effects of the COVID-19 pandemic on the presentation of other urgent and emergent surgical conditions are also warranted.

## Author Contributions

All authors made substantial contributions to the conception and design of this study. R.T., M.K., and C.M. contributed to the data acquisition and analysis, and prepared the manuscript. M.K., P.C., J.P., S.F., P.S. and C.M. provided expertise that influenced the study design and data interpretation. All authors have drafted or critically revised the manuscript and give final approval for this version to be published.

## Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

## Data Statement

The data that support the findings of this study are available from the NYU Grossman School of Medicine. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the authors with the permission of the NYU Grossman School of Medicine.

## References

1. Klein MJ, Frangos SG, Krowsoski L, et al. Acute care surgeons' response to the COVID-19 pandemic: Observations and strategies from the epicenter of the American crisis. *Ann Surg.* 2020;272(2):e66-e71.
2. Bernstein LSF. *Patients with Heart Attacks, Strokes and Even Appendicitis Vanish from Hospitals.* Washington, D.C: The Washington Post; 2020.
3. Garcia S, Albaghdadi MS, Meraj PM, et al. Reduction in ST-segment elevation cardiac catheterization laboratory activations in the United States during COVID-19 pandemic. *J Am Coll Cardiol.* 2020;75(22):2871-2872.
4. Hartnett KP, Kite-Powell A, DeVies J, et al. Impact of the COVID-19 pandemic on emergency department visits - United States, January 1, 2019-May 30, 2020. *MMWR Morb Mortal Wkly Rep.* 2020;69(23):699-704.
5. Sartelli M, Chichom-Mefire A, Labricciosa FM, et al. The management of intra-abdominal infections from a global perspective: 2017 WSES guidelines for management of intra-abdominal infections. *World J Emerg Surg.* 2017; 12:29.
6. Tsao HM, Sun YC, Liou DM. A rational approach to estimating the surgical demand elasticity needed to guide manpower reallocation during contagious outbreaks. *PLoS One.* 2015;10(4):e0122625.
7. Ganesh R, Lucocq J, Ekpete NO, et al. Management of appendicitis during COVID-19 pandemic; short-term outcomes. *Scott Med J.* 2020;65(4):144-148.
8. Neufeld MY, Bauerle W, Eriksson E, et al. Where did the patients go? Changes in acute appendicitis presentation and severity of illness during the coronavirus disease 2019 pandemic: A retrospective cohort study. *Surgery.* 2021; 169(4):808-815.
9. Orthopoulos G, Santone E, Izzo F, et al. Increasing incidence of complicated appendicitis during COVID-19 pandemic. *Am J Surg.* 2021;221(5):1056-1060.
10. Tankel J, Keinan A, Blich O, et al. The decreasing incidence of acute appendicitis during COVID-19: A retrospective multi-centre study. *World J Surg.* 2020;44(8): 2458-2463.
11. Kohler F, Muller S, Hendricks A, et al. Changes in appendicitis treatment during the COVID-19 pandemic - A systematic review and meta-analysis. *Int J Surg.* 2021;95: 106148.
12. Ceresoli M, Coccolini F, Magnone S, et al. The decrease of non-complicated acute appendicitis and the negative appendectomy rate during pandemic. *Eur J Trauma Emerg Surg.* 2021;47(5):1359-1365.
13. Ahmed T, Lodhi SH, Kapadia S, Shah GV. Community and healthcare system-related factors feeding the phenomenon of evading medical attention for time-dependent emergencies during COVID-19 crisis. *BMJ Case Rep.* 2020; 13(8):e237817.
14. Masroor S. Collateral damage of COVID-19 pandemic: Delayed medical care. *J Card Surg.* 2020;35(6): 1345-1347.
15. NYC.gov. Get the Medical Care You Need. Online: NYC.gov. 2020. p. <https://www1.nyc.gov/assets/doh/downloads/pdf/covid/covid-19-medical-care-you-need.pdf>
16. Florida RR-PA, Storper M. Cities in a post-COVID world. *SAGE Urban Stud J.* published online. June 27, 2021.
17. Bickell NA, Aufses AH Jr., Rojas M, Bodian C. How time affects the risk of rupture in appendicitis. *J Am Coll Surg.* 2006;202(3):401-406.
18. Humes DJ, Simpson J. Acute appendicitis. *BMJ.* 2006; 333(7567):530-534.
19. Dreifuss NH, Schlottmann F, Sadava EE, Rotholtz NA. Acute appendicitis does not quarantine: surgical outcomes of laparoscopic appendectomy in COVID-19 times. *Br J Surg.* 2020;107(10):e368-e369.
20. Finkelstein P, Picado O, Muddasani K, et al. A Retrospective analysis of the trends in acute appendicitis during the COVID-19 pandemic. *J Laparoendosc Adv Surg Tech A.* 2021;31(3):243-246.
21. Gerall CD, DeFazio JR, Kahan AM, et al. Delayed presentation and sub-optimal outcomes of pediatric patients with acute appendicitis during the COVID-19 pandemic. *J Pediatr Surg.* 2021;56(5):905-910.



22. Patel VK, Ye K, In H, et al. Non-operative management for acute appendicitis during the COVID-19 pandemic does not increase the rate of complications. *J Gastrointest Surg.* 2021;25(5):1327-1329.
23. Gershengorn HB, Patel S, Shukla B, et al. Association of race and ethnicity with COVID-19 test positivity and hospitalization is mediated by socioeconomic factors. *Ann Am Thorac Soc.* 2021;18(8):1326-1334.
24. DiMaggio C, Klein M, Berry C, Frangos S. Black/African American Communities are at highest risk of COVID-19: spatial modeling of New York City ZIP Code-level testing results. *Ann Epidemiol.* 2020;51:7-13.