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Where did the patients go? Changes in acute appendicitis presentation and severity of illness during the coronavirus disease 2019 pandemic: A retrospective cohort study

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ABSTRACT

Background: The coronavirus disease 2019 pandemic restricted movement of individuals and altered provision of health care, abruptly transforming health care-use behaviors. It serves as a natural experiment to explore changes in presentations for surgical diseases including acute appendicitis. The objective was to determine if the pandemic was associated with changes in incidence of acute appendicitis compared to a historical control and to determine if there were associated changes in disease severity.

Methods: The study is a retrospective, multicenter cohort study of adults ($N = 956$) presenting with appendicitis in nonpandemic versus pandemic time periods (December 1, 2019–March 10, 2020 versus March 11, 2020–May 16, 2020). Corresponding time periods in 2018 and 2019 composed the historical control. Primary outcome was mean biweekly counts of all appendicitis presentations, then stratified by complicated ($n = 209$) and uncomplicated ($n = 747$) disease. Trends in presentations were compared using difference-in-differences methodology. Changes in odds of presenting with complicated disease were assessed via clustered multivariable logistic regression.

Results: There was a 29% decrease in mean biweekly appendicitis presentations from 5.4 to 3.8 (rate ratio = 0.71 [0.51, 0.98]) after the pandemic declaration, with a significant difference in differences compared with historical control ($P = .003$). Stratified by severity, the decrease was significant for uncomplicated appendicitis (rate ratio = 0.65 [95% confidence interval 0.47–0.91]) when compared with historical control ($P = .03$) but not for complicated appendicitis (rate ratio = 0.89 [95% confidence interval 0.52–1.52]); ($P = .49$). The odds of presenting with complicated disease did not change (adjusted odds ratio 1.36 [95% confidence interval 0.83–2.25]).

Conclusion: The pandemic was associated with decreased incidence of uncomplicated appendicitis without an accompanying increase in complicated disease. Changes in individual health care-use behaviors may underlie these differences, suggesting that some cases of uncomplicated appendicitis may resolve without progression to complicated disease.

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Introduction

Coronavirus disease 2019 (COVID-19) was declared a global pandemic on March 11, 2020 by the World Health Organization.¹ While the international and American responses have been

heterogeneous, the pandemic significantly affected movement of individuals and hospital policies worldwide. Studies have begun to investigate the impact of the pandemic on acute or emergency conditions traditionally requiring urgent medical or surgical attention.^{2–5} A recent study of the Veterans Affairs health care system noted significant declines in admissions for 6 acute conditions, including appendicitis.⁶ Reasons for these declines were posited to include fear of exposure to COVID-19 leading to shifts in individual health care-use behaviors.^{3,6} Multiple studies conducted after the Severe Acute Respiratory Syndrome and Middle Eastern Respiratory Syndrome outbreaks showed similar declines in emergency department (ED) evaluations and hospital admissions.^{7–10} Decreased health care-use for acute conditions may manifest as delayed presentations and increased severity of disease.^{11,12}

While appendectomy for acute appendicitis (AA) is a common surgical procedure, hypotheses vary as to its pathophysiology and natural history. Traditionally, it has been thought that AA inexorably led to perforation without treatment. A growing body of evidence, however, suggests that uncomplicated and complicated (perforated with or without abscess) AA show different epidemiologic trends.¹³ This may reflect differences in natural history between a mild or indolent form and a progressive form of the disease. Some cases of uncomplicated AA resolve with antibiotics^{13–15} or with no treatment.^{16,17} Some have gone so far as to hypothesize that uncomplicated and complicated appendicitis are 2 separate disease processes entirely.¹⁸ Differences in these epidemiologic trends have been attributed to multiple factors including health care–use behaviors, care patterns such as frequency of computed tomography (CT) scan use in the evaluation of abdominal pain,¹³ and timely access to high-quality surgical care.^{18–22} Perforation rates (ie, the proportion of perforated cases out of all cases of AA) have been identified by some health-services researchers as a proxy for access to care.^{21,22} Given potential differences in the natural history of uncomplicated and complicated appendicitis, the use of perforation rates as a marker for access to care has been questioned.¹⁹ The COVID-19 pandemic functions as a natural experiment to test whether dramatic shifts in individual behaviors were associated with short-term changes in the incidence of AA, and if these changes, including delays in presentation, were associated with an increase in the number of patients who presented with severe disease.

The objective of this geographically diverse, multi-institutional study was to assess whether the pandemic was associated with a change in the overall incidence of AA using the robust, quasi-experimental difference-in-differences (DID) methodology. Furthermore, we evaluated whether trends in incidence differed between complicated and uncomplicated AA. There were 2 secondary objectives: to determine whether the odds of presenting with complicated disease differed for patients who presented in the 2.5 months after the pandemic declaration compared to patients who presented in a nonpandemic time frame. We also evaluated whether measures of health care use changed after the pandemic declaration. We hypothesized that there would be a decrease in overall AA presentations after March 11, 2020, and that this decrease would be driven by reductions in the incidence of uncomplicated AA.

Methods

Study approval and data sources

The study was deemed exempt by the Boston University Medical Campus Institutional Review Board (IRB) (H-40436). Participating institutions obtained their own IRB approval or ceded oversight to

the primary site IRB. Demographic and management data were collected from electronic health records at each institution, and chart review was conducted in compliance with Health Insurance Portability and Accountability Act guidelines. The 5 participating centers are located in Boston, Massachusetts, Charleston, South Carolina, Palm Beach, Florida, Denver, Colorado, and Seattle, Washington. All are teaching hospitals, and 4 meet the definition of safety net hospital.

Cohort description

This was a retrospective cohort of 956 participants. Patients were included if they were age ≥ 18 years and presented to a participating institution with a diagnosis of AA from December 1, 2019 to May 16, 2020 and from the same time periods in 2018 and 2019, which composed the historical control for DID analysis. Eligible patients were identified using International Classification of Disease, version 10, codes and/or internally maintained registries and included patients managed both operatively and non-operatively. Those who underwent elective interval appendectomies or appendectomy for diagnoses other than AA (eg, neoplasm) were excluded.

Exposure

The exposure of interest was the period following the global declaration of the COVID-19 pandemic (March 11, 2020–May 16, 2020). A sensitivity analysis was also performed, where the exposure period was specific to each institution's statewide stay-at-home order, which ranged from March 24, 2020 to April 9, 2020. For this sensitivity analysis, calendar dates were offset such that each institution's "time zero" (corresponding to the date of the state stay-at-home order) was aligned, and pre-/post-time periods were adjusted accordingly.

Primary outcomes

The primary outcome was the difference in mean biweekly count of AA presentations per institution before and after the pandemic declaration as compared to the same time periods in the historical control. A similar assessment was made after AA was stratified by uncomplicated and complicated disease. Rather than simply comparing the postdeclaration timeframe (mid-March to May) to the prepandemic timeframe (December to mid-March), we used a recent historical control to account for previously described seasonality of appendicitis incidence.^{23,24} Biweekly counts from the same period in 2018 and 2019 were summed across all institutions and averaged to create the historical control. When creating the classifications of uncomplicated and complicated appendicitis, we used the validated the American Association for the Surgery of Trauma grading for acute appendicitis.²⁵ Extensive chart review was performed for all cases to accurately classify cases as uncomplicated or complicated. Uncomplicated appendicitis was defined as CT findings of inflammation localized to the appendix for nonoperative cases and an acutely inflamed appendix for operative cases (which could include possible gangrene and/or necrosis without evidence of perforation or abscess). Complicated appendicitis was defined as CT findings of phlegmon or abscess for nonoperative cases and a frankly perforated appendix with local contamination, abscess, or generalized peritonitis for operative cases. These definitions correspond to validated American Association for the Surgery of Trauma appendicitis grades I to II for uncomplicated and grades III to V for complicated appendicitis.²⁶ Data abstractors used standardized definitions, and ambiguous cases were reviewed by surgeon experts on the research team.

Secondary and additional outcomes

The secondary outcome was the odds of presentation with complicated appendicitis following the declaration of pandemic compared to all presentations prior to the declaration. Additional outcomes included duration of stay (in days), duration of symptoms prior to presentation (in days), 30-day readmission (defined as return to the ED or hospital admission), and need for reintervention. Reintervention was defined as an unplanned return to the operating room or need for radiologically guided drain placement.

Covariates

Demographic data was collected for each patient including sex, age, race/ethnicity, primary language, rurality, and presence and type of insurance. Rurality was determined via zip code using the Federal Office of Rural Health Policy eligibility criteria.²⁷ Additional clinical variables included operative versus nonoperative management and requirement for a drainage procedure.

Statistical analysis

All statistical analysis was performed using SAS Studio 3.8 software (SAS Institute, Inc, Cary, NC). Significance was set at $\alpha = 0.05$, and hypothesis tests were 2-sided. Descriptive statistics are reported as means with standard deviations for continuous, normally distributed variables. Categorical variables are reported as number and percent. A comparison of demographic and clinical management variables of those patients presenting before and after the pandemic declaration was performed using Rao-Scott χ^2 test²⁸ for dichotomous and categorical variables and a 1-way analysis of variance with adjustment for clustered data for continuous variables. For all analyses using combined data, to account for clustering by hospital, we used a small sample adjustment with unbiased estimating equations, using a variance components covariance structure with a sandwich estimator of variance.²⁹ Increasingly used in public health and medical arenas, DID allows for the examination of the association between a particular event or shift in policy (in this case, the declaration of pandemic) and an outcome. It addresses the problem of a traditional pre-/postanalysis with the inclusion of a control group not exposed to the shift in an effort to control for secular changes and determine the independent effect of the shift in policy. Critical to this methodology are pre-event parallel trends, which assume that prior to the shift in policy, the 2 groups were the same.³⁰ In our study, DID analysis of Poisson regressions was performed to compare biweekly counts of AA presentations prior to and following the pandemic declaration. The historical control was generated from a cumulative average of 2018 and 2019 data and was compared to the equivalent biweekly intervals in 2020. The DID analysis was first done for each individual institution; counts were then combined across all institutions for the primary analysis. For combined data, the parallel trends assumption for DID analysis was met with visual inspection and with no significant difference between 2020 and historical control prior to the pandemic (β 0.08 [SE = 0.07]; $P = .27$). Additionally, “common shocks”³⁰ were assumed given no differences in demographic or clinical management variables prior to and after the declaration of pandemic. The use of a historical control from the same institutions alleviated concern for spillover effects. Means were compared pre- and postpandemic declaration with associated rate ratios (RR).

Odds of presenting with complicated appendicitis before and after the declaration was assessed with multivariable logistic regression modeling and corresponding odds ratios (OR). For this analysis, all patients with missing demographic data were

excluded. Those patients who presented after the declaration of pandemic on March 11, 2020 were in the exposed group, and those patients who presented during all other time periods were in the unexposed group. Variables included in the multivariable logistic regression were those with a univariable association ($P < .15$) and clinical relevance. Multivariable logistic regression models were then created for 30-day readmission and need for reintervention. For duration of stay and duration of symptoms prior to presentation, multivariable Poisson regressions were performed.

Results

Cohort characteristics

There were 956 patients included in the DID analysis. Multivariable regression modeling for odds of presenting with complicated disease included 931 patients with complete demographic data. There was no significant difference in patient demographics nor in clinical management before and after the declaration of pandemic (Table 1). The majority of patients were non-Hispanic White or Hispanic. Primary language spoken was English, and the majority had private insurance followed by Medicaid/state government insurance. Most patients presented with uncomplicated appendicitis, and the majority of both uncomplicated (88%) and complicated cases (76%) were managed surgically.

Appendicitis presentations before and after declaration

Four of 5 institutions had a decrease in mean biweekly appendicitis counts following the pandemic declaration, though this decrease was only significant for institution 1 (Table II). When data from all hospitals were combined (Fig 1), there was a significant negative DID between the pre- and postdeclaration periods in 2020 compared to the historical control (β -0.43 [SE = 0.14]; $P = .003$). Mean biweekly appendicitis presentations in the postdeclaration period was 3.80 vs 5.37 (RR = 0.71 [0.51, 0.98]; $P = .04$) before the declaration, compared to 5.40 vs 4.97 in the historical control (RR = 1.09 [0.83, 1.41]; $P = .53$) (Table II). This represents an approximate 29% decrease in mean AA presentations following the worldwide declaration of pandemic. Sensitivity analysis using each state's stay-at-home order date yielded similar results. There was a decrease in mean biweekly appendicitis presentations (Fig 2) and a significant negative DID comparing 2020 to the historical control (β -0.42 [SE = 0.17]; $P = .02$).

Uncomplicated versus complicated appendicitis before and after declaration

Appendicitis counts were then stratified into uncomplicated and complicated cases (Fig 3). For uncomplicated appendicitis, there was a significant negative DID between the pre- and postdeclaration periods in 2020 compared to historical control (β -0.51 [SE = 0.16]; $P = .03$). In 2020, mean biweekly uncomplicated appendicitis presentations decreased by 35% from 4.17 to 2.72 (RR = 0.65 [95% confidence interval {CI} 0.47–0.91]; $P = .01$) compared to no change (3.94–4.30) for the historical control (RR = 1.09 [95% CI 0.82–1.45]; $P = .55$) (Table III). The DID for complicated appendicitis was not significant (β -0.19 [SE = 0.28]; $P = .49$). Specifically, mean biweekly complicated appendicitis presentations were 1.17 and 1.04 for the 2020 pre- and postpandemic declaration periods, respectively (RR = 0.89 [95% CI 0.52–1.52]; $P = .66$), compared to 1.06 and 1.14 in the historical control (RR = 1.08 [95% CI 0.77–1.50]; $P = .65$) (Table III).

Table I
Demographic and clinical management variables for patients presenting with AA pre- and postdeclaration of pandemic

	Before declaration of pandemic (n = 840)	After declaration of pandemic (n = 91)	P value
Appendicitis presentations (n, %)			.20
Uncomplicated	659 (78.45)	66 (72.53)	
Complicated	181 (21.55)	25 (27.47)	
Age (mean, STD)	37.26 (14.73)	38.40 (14.08)	.47
Female patients (n, %)	350 (41.67)	44 (48.35)	.22
Race/ethnicity (n, %)			.24
NH-White	346 (41.19)	46 (50.55)	
NH-Black	98 (11.67)	11 (12.09)	
NH-Asian	36 (4.29)	4 (4.40)	
NH-Other	26 (3.10)	0 (0.00)	
Hispanic	334 (39.76)	30 (32.97)	
Primary language (n, %)			.35
English	594 (70.71)	66 (72.53)	
Spanish	215 (25.60)	21 (23.08)	
Other	31 (3.69)	4 (4.40)	
Insurance status (n, %)			.06
Uninsured	133 (15.83)	14 (15.38)	
Public-Medicaid/MH	176 (20.95)	28 (30.77)	
Public-Medicare	48 (5.71)	1 (1.10)	
Private	483 (57.50)	48 (52.75)	
Rural (n, %)	28 (3.33)	1 (1.10)	.24
Treatment if uncomplicated (n, %)			.29
Antibiotics	79 (11.99)	5 (7.58)	
Surgery	580 (88.01)	61 (92.42)	
Treatment if complicated (n, %)			.30
Antibiotics	46 (25.41)	4 (16.00)	
Surgery	135 (74.59)	21 (84.00)	
Need for drainage	20 (11.05)	3 (12.00)	.89

Missing data has been excluded.

MH, MassHealth; NH, non-Hispanic; STD, standard deviation.

Table II
Mean biweekly appendicitis count for each institution and all hospitals combined

Institution	Historical				2020			
	Predeclaration mean (SD)	Postdeclaration mean (SD)	RR (95% CI)	P value	Predeclaration mean (SD)	Postdeclaration mean (SD)	RR (95% CI)	P value
I (n = 270)	8.00 (1.41)	6.90 (1.29)	0.86 (0.56–1.31)	.49	8.43 (3.05)	3.60 (1.52)	0.43 (0.25–0.72)	.002
II (n = 161)	3.71 (0.64)	5.20 (1.96)	1.40 (0.81–2.41)	.23	4.00 (1.15)	3.20 (1.64)	0.80 (0.43–1.48)	.48
III (n = 145)	4.21 (1.19)	3.80 (1.04)	0.90 (0.51–1.60)	.73	3.14 (1.21)	3.80 (2.17)	1.21 (0.65–2.23)	.54
IV (n = 85)	1.93 (1.37)	2.90 (0.96)	1.50 (0.72–3.16)	.28	2.57 (2.64)	1.60 (0.55)	0.62 (0.27–1.43)	.22
V (n = 295)	7.29 (1.73)	8.40 (2.30)	1.15 (0.77–1.73)	.49	8.86 (2.12)	6.80 (1.92)	0.77 (0.51–1.17)	0.22
All institutions (N = 956)	4.97 (2.69)	5.40 (2.51)	1.09 (0.83–1.41)	.53	5.37 (3.43)	3.80 (2.29)	0.71 (0.51–0.98)	.04

Presented are means stratified by year with associated RR for each institution.

Odds of complicated appendicitis postdeclaration

Univariable and multivariable logistic regression were used to determine the odds of a presentation with complicated appendicitis in the postdeclaration period compared to all other timeframes (Table IV). In both the unadjusted model (OR 1.38 [95% CI 0.84–2.25]; $P = .20$) and the model adjusted for key covariates including age, sex, language, rurality, and insurance status, there was no significant increase in the odds that patients presented with complicated appendicitis following the declaration of pandemic compared to patients in nonpandemic time periods (adjusted OR 1.36 [95% CI 0.83–2.25]; $P = .23$).

Additional outcomes postdeclaration

After adjusting for age, race, insurance status, and severity of appendicitis, mean duration of symptoms increased from 3.26 to 4.32 days following the declaration of pandemic (RR 1.32 [95% CI 1.00–1.76]; $P = .05$). In the multivariable model adjusted for age, race/ethnicity, insurance status, and severity of appendicitis, mean

duration of stay decreased from 2.40 to 1.83, reflecting over a half day decrease in average duration of stay (RR 0.73 [95% CI 0.60–0.88]; $P = .001$) (Table IV). There were no significant differences in the odds of reintervention after adjusting for sex, age, race, language, insurance status, and disease severity or in 30-day readmission after adjusting for sex, race, insurance status, and disease severity (Table IV).

Discussion

DID analysis, a quasi-experimental methodology, demonstrated a significant decrease in presentations for AA after the global declaration of pandemic by the World Health Organization on March 11, 2020, as compared to the 2018/2019 historical control. These findings in our combined data are strengthened by similar trends at 4 of the 5 institutions. This decrease was driven by a decline in the number of uncomplicated cases, while complicated cases remained relatively constant. Contrary to other small single-institution studies, case series, and anecdotal evidence thus far, we demonstrated that the odds of presenting with

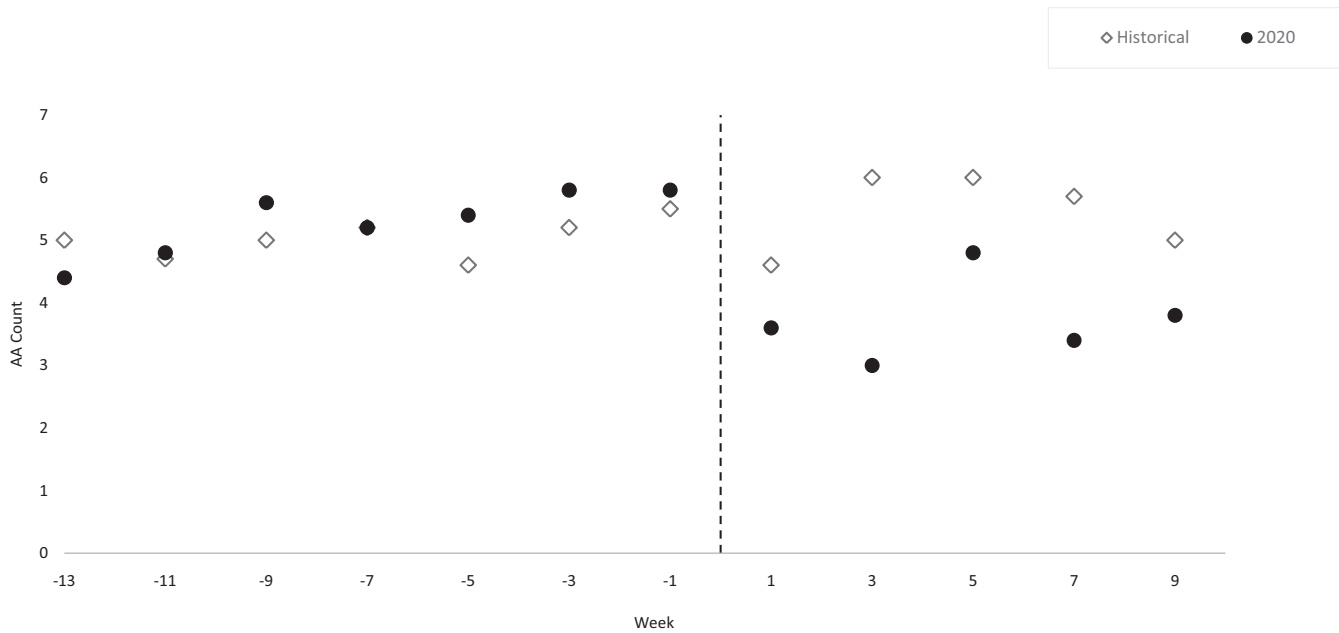


Fig 1. Average biweekly appendicitis counts across all institutions pre and postdeclaration (2020) compared with historical control. Dashed line corresponds to the declaration of pandemic ($N = 956$).

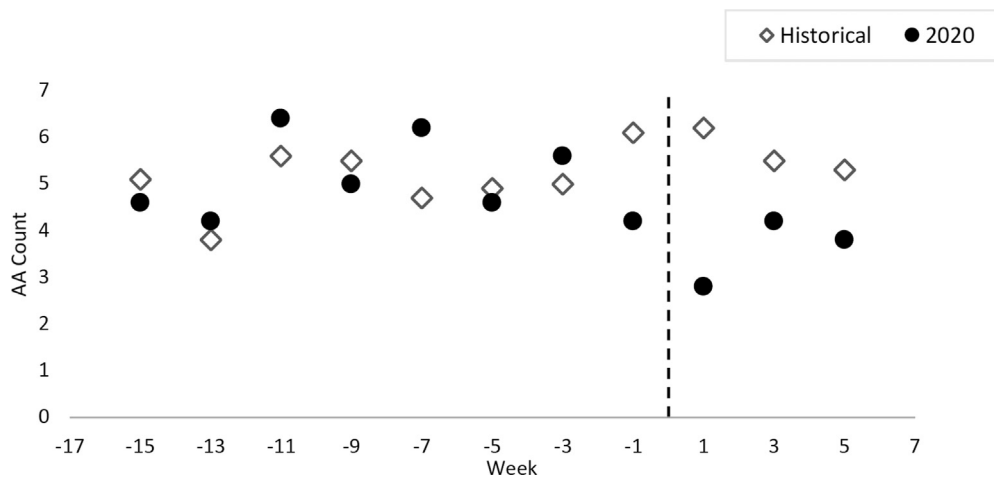


Fig 2. Average biweekly appendicitis counts across institutions before and after state-specific stay-at-home order compared with historical control. Dashed line corresponds to aligned “time zero” corresponding to the date of each institution’s state-specific stay-at-home order ($N = 956$). Only those weeks with data from all 5 institutions are displayed.

complicated appendicitis was no different prior to or after the declaration of pandemic. Although a few studies have investigated changes in volume and severity of appendicitis during the pandemic,^{4-6,11,12,31-34} our study has several key advantages. This is a multi-institution cohort derived from geographically and demographically diverse sites across the United States. Rather than a simple pre/post methodology that might be confounded by seasonal ecological trends, we used a more rigorous DID methodology. Finally, this study investigated temporal trends in AA incidence stratified into complicated and uncomplicated disease and was designed to formally test the hypothesis that changes in overall incidence were driven mostly by changes in uncomplicated appendicitis. This multistate study was designed to address the effects of changed health care–use behaviors on the incidence of AA beyond what has been observed in a single hospital,³⁴ city,⁴ or health care system.⁶ Our study corroborates the findings of 2 recent investigations^{4,6} and strengthens their conclusions via a more

generalizable study population that is diverse in terms of geography, sex, age, race/ethnicity, and insurance status.

Our results support the growing body of evidence that uncomplicated appendicitis does not always progress to complicated disease in the absence of surgery or antibiotics.^{13,17,18,19} The decrease in uncomplicated cases following the pandemic declaration did not appear to lead to a corresponding increase in complicated cases; in fact, complicated cases remained stable in all time periods. A study of 4 hospitals in Jerusalem, Israel found similar results and hypothesized that the decline in AA was due to cases resolving without admission or intervention.⁴ Previous work has hypothesized that health care–use behaviors may be 1 contributing factor in the nonrandom distribution of acute uncomplicated appendicitis¹⁹ and that higher proportions of complicated disease in some sub-populations may be related—at least in part—to reduced detection of some cases of uncomplicated disease rather than increased relative risk of perforation.¹⁸ The acute onset of the COVID-19 pandemic

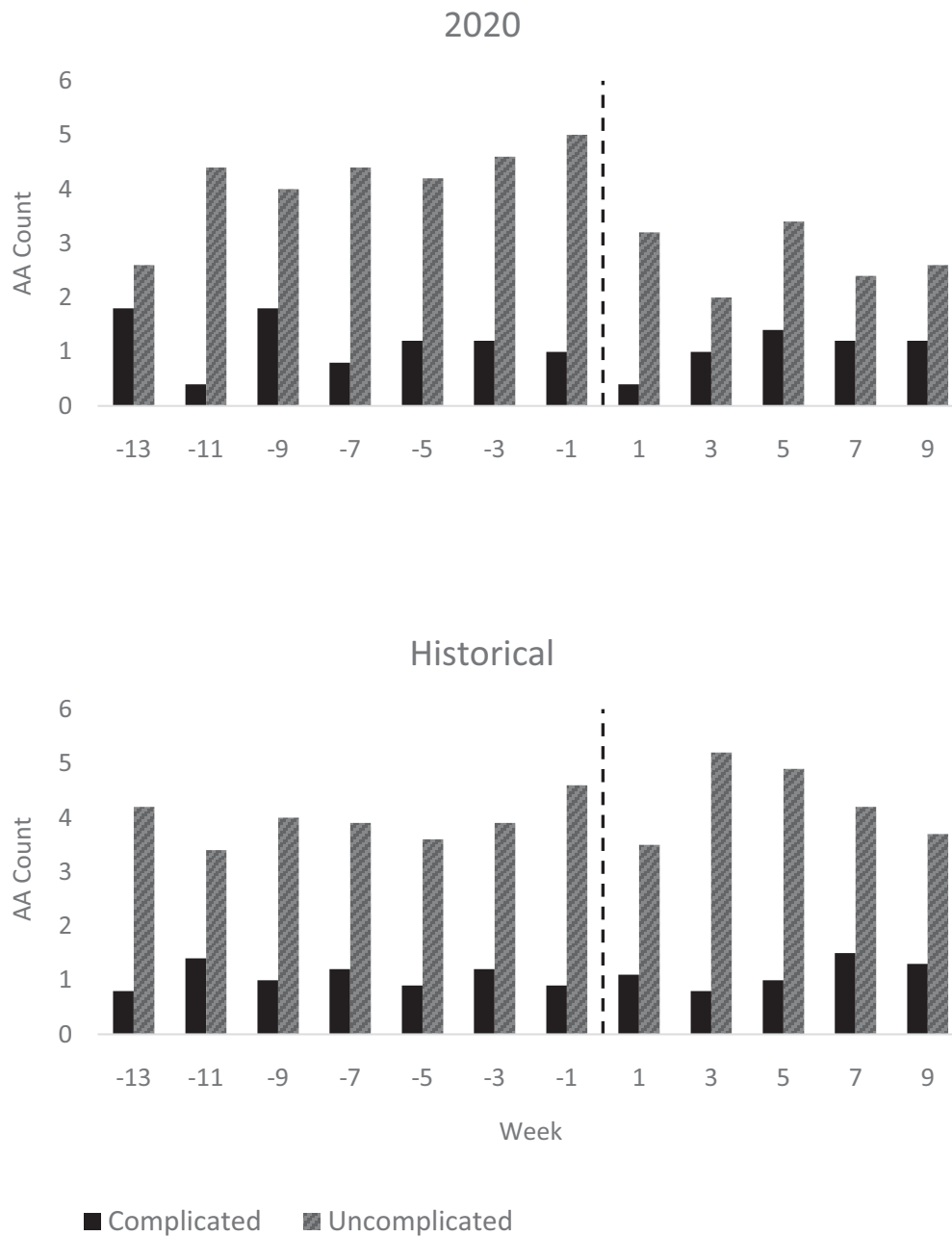


Fig 3. Biweekly average uncomplicated and complicated appendicitis counts across institutions in 2020 compared to historical control. Dashed line corresponds to the declaration of pandemic ($N = 956$).

Table III
Mean biweekly appendicitis counts stratified by uncomplicated and complicated presentation across institutions

Appendicitis	Historical				2020			
	Predeclaration mean (SD)	Postdeclaration mean (SD)	RR (95% CI)	P value	Predeclaration mean (SD)	Postdeclaration mean (SD)	RR (95% CI)	P value
Uncomplicated ($n = 725$)	3.94 (2.25)	4.30 (2.22)	1.09 (0.82–1.45)	.55	4.17 (2.83)	2.72 (1.65)	0.65 (0.47–0.91)	.01
Complicated ($n = 206$)	1.06 (0.76)	1.14 (0.64)	1.08 (0.77–1.50)	.65	1.17 (1.20)	1.04 (1.06)	0.89 (0.52–1.52)	.66

Presented are means stratified by year with associated RR.

and associated dramatic shifts in health care-use behaviors created a natural experiment from which we can draw 2 conclusions: (1) some cases of AA appear to resolve without medical or surgical

intervention and (2) disruptions in use of timely surgical care do not necessarily lead to corresponding increases in presentations of complicated appendicitis.

Table IV
Unadjusted and adjusted measures of association for severity disease and hospital outcomes

	Unadjusted OR/RR (95% CI)	P value	Adjusted OR/RR (95% CI)	P value
Complicated appendicitis	1.38 (0.84–2.26)	.20	1.36 (0.83–2.25)	.23
Duration of symptoms	1.33 (1.00–1.76)	.05	1.32 (1.00–1.76)	.05
Duration of stay	0.76 (0.62–0.94)	.01	0.73 (0.60–0.88)	.001
Readmission	0.74 (0.33–1.67)	.47	0.71 (0.29–1.69)	.44
Reintervention	0.61 (0.14–2.60)	.50	0.64 (0.13–3.31)	.60

Analysis excludes patients with missing demographic or outcome data.

This is in contrast to a few small studies that have noted increases in disease severity among those who presented during the pandemic period.^{31–34} Most notably, a single-institution study using a similar DID methodology found, as in the current investigation, that the incidence of appendicitis, particularly uncomplicated appendicitis, decreased. Their study, which defined complicated versus uncomplicated via International Classification of Disease, 10th revision, codes not direct chart review, found an increase in the proportion of perforated and gangrenous appendicitis cases following the pandemic declaration when compared to historical years.³⁴ As our stratified data demonstrate, the use of proportions is potentially problematic if uncomplicated and complicated disease show different patterns within an overall decrease in incidence. That study is further limited by a small sample size from a single institution.

Among our additional outcomes, duration of stay was significantly reduced after the pandemic declaration. Many hospitals prioritized expeditious discharge during the peak of the pandemic, and that is the likely explanation for these findings. Duration of symptoms increased by approximately 1 day, but there was no associated increase in the odds of presenting with complicated disease. This supports the hypothesis that not all uncomplicated AA progresses to complicated disease when presentation to the hospital is comparatively longer. Neither the odds of 30-day readmission nor need for reintervention were significantly increased after the declaration of pandemic. Of note, there was only 1 patient at all 5 institutions who tested positive for COVID-19, thus a positive test was not a significant factor in determining clinical management strategies during this time period.

Limitations

In some participating institutions, billing codes were used to identify cases of AA, which may have resulted in failure to identify all cases (other institutions maintain a registry of all emergency general surgery consultations, and billing codes were not used). There is, however, no reason that identifying cases via billing codes would have affected patient identification differently in different time periods, thus this is unlikely to be a source of bias. Of note, following patient identification, all charts were individually reviewed to classify severity of disease. Given that we only categorized appendicitis as uncomplicated or complicated, we were unable to determine whether there were changes within each category; for example, within the overall category “complicated appendicitis,” certain subcategories may have shown increases or decreases, and several papers published in the COVID era have described anecdotal evidence of patients presenting with Class V disease.^{11,33,35,36} The short follow-up period may have limited our ability to track late-occurring complications. Given that most appendicitis-related complications occur in the short term, the potential impact of late complications should be minimal.³⁷ The known seasonal variation in appendicitis admissions^{23,24} could have impacted counts in the postdeclaration period, though this was mitigated by the use of the DID methodology. We were unable

to include patients who might have been treated for uncomplicated appendicitis as an outpatient. It is also possible that decreased presentation to the hospital may have resulted from decreased access to outpatient evaluations amid the transition to telemedicine. However, most patients reporting symptoms concerning for AA during a telemedicine encounter would have been directed to the ED. Furthermore, should AA patients have not been directed to the ED and they improved at home, this would support the central findings of our study. Finally, this is not a population-based study and, thus, we were unable to determine if changes in referral patterns or patient hospital selection following the pandemic declaration led to the changes detected in this cohort. A population-based study would certainly mitigate against this limitation,¹⁹ and when large databases are available to study the 2020 timeframe, such a study should be prioritized. However, 4 of the 5 hospitals in this geographically diverse study experienced similar decreases in uncomplicated disease. If changes in hospital choices and referral patterns are responsible for the results presented in this study, such changes would have occurred simultaneously at 4 institutions across the country, which, in our view, is unlikely.

In conclusion, this study demonstrated a significant decrease in presentations for AA following the pandemic declaration compared to a historical control, using robust DID methodology. This decrease was driven by reduced cases of uncomplicated AA, and there was no increase in the odds of complicated AA presentations following the March 11th pandemic declaration. This study is consistent with the hypothesis that all cases of AA do not necessarily progress to complicated disease even in the absence of treatment and that individual health care-use behaviors may drive variations in incidence. Disruptions in the usual pathways of acute surgical care caused by the COVID-19 pandemic did not result in a shift towards a higher incidence of complicated AA. The findings further suggest that health-services researchers must be cautious when using perforation rates (ie, proportions of complicated appendicitis out of all cases of AA that present for care) as markers of access to timely and high-quality surgical care, since the “denominator” of such proportions appears susceptible to health care-use behaviors. Most importantly, these findings require fresh reassessment of the natural history of the disease process “appendicitis” that includes investigations into how and why some patients develop progressive disease while others do not.

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Conflict of interest/Disclosures

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