



## Long-term results on the severity of acute appendicitis during COVID-19 pandemic



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### ABSTRACT

**Background:** Acute appendicitis cases increased in severity following COVID-19–related restrictions in March, 2020. We investigated if similar changes occurred during Wave 2.

**Methods:** Acute appendicitis patients during Wave 1 were grouped 8 weeks before (Group A) and after (Group B) stay-at-home restrictions were initiated on March 15, 2020. Cases in Wave 2 were grouped 8 weeks before (Group C) and after (Group D) November 6, 2020. Groups were compared to equivalent time frames in 2018/2019.

**Results:** Group A versus B revealed 42.6% decrease (confidence interval: –59.4 to –25.7) in uncomplicated appendicitis and 21.1% increase (confidence interval: 4.8–37.3) in perforated appendicitis. Similar patterns were noted comparing Group C versus D without statistical significance. The changes seen in Wave 1 were significantly different than in 2018/2019. This trend continued in Wave 2.

**Conclusion:** Similar to Wave 1, acute appendicitis cases increased in severity during wave 2 of COVID-19, but with less prominence.

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### INTRODUCTION

The effects of the global pandemic caused by coronavirus SARS-CoV-2 (COVID-19) on travel restrictions, social isolation, and health care limitations have opened many discussions revolving around the effectiveness of timely management of surgical diseases, such as acute appendicitis [1]. We previously published a study evaluating the complexity of acute appendicitis during the "first wave" of COVID-19 in the spring months of 2020 using the initiation of stay-at-home restrictions as both a marker of the first wave and as a potential explanation for the increased severity of acute surgical diseases during the beginning of the pandemic in Massachusetts. Our study showed a significant decrease in the incidence of acute uncomplicated appendicitis with a simultaneous significant increase in perforated and gangrenous appendicitis during the first wave of COVID-19 which could indicate a lack of seeking timely care during that period [2].

However, like many states, Massachusetts experienced a "second wave" of COVID-19 infections during the fall and winter months of 2020. Like the first wave, the second wave was hallmarked by an

Executive Order on social gatherings, early business closures, and face-covering protocols [3]. Another stay-at-home advisory was implemented during these months, as well as an effort at the hospital level to limit elective surgical cases [4]. We therefore sought to determine if the changes in appendicitis seen during the first wave of COVID-19 persisted in the second wave.

### MATERIALS AND METHODS

This study was a continuation of our previous retrospective cohort investigation of acute appendicitis during the COVID-19 pandemic at Baystate Medical Center (BMC), a 720-bed, tertiary care, regional academic medical center currently serving a population of approximately 850,000 people in western Massachusetts.

Our study period included all adult and pediatric admissions from January 1, 2018, to December 31, 2020, using *International Classification of Diseases (ICD-10)* diagnosis codes (Appendix A) for uncomplicated and complicated (defined as perforation of the appendix, gangrenous appendicitis, and/or abscess/phlegmon) acute appendicitis. The primary outcome of the study was to identify the number of patients presenting with acute appendicitis before and after the beginning of COVID-19–related restrictions in both spring and winter months at BMC as well as the proportion of patients with complicated acute appendicitis disease as defined by postoperative diagnosis.

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**Table 1**  
Comparison of treatment modalities in 2020

	Baseline time period			COVID time period			Difference in difference (95% CI)
	2020 Group A n (%)	2020 Group Bn (%)	Absolute difference (95% CI)	2020 Group Cn (%)	2020 Group Dn (%)	Absolute difference (95% CI)	
Laparoscopic appendectomy	63 (91.3)	39 (86.7)	−4.6% [−16.6 to 7.3]	59 (88.1)	43 (91.5)	4.2% [−5.9 to 14.4]	−8.9% [−24.6 to 6.9]
Open appendectomy	1 (1.4)	0 (0.0)	–	1 (1.5)	1 (2.1)	0.6% [−4.6 to 5.8]	–
Abdominal washout and drain placement	0 (0.0)	2 (4.4)	–	1 (1.5)	0 (0.0)	−8.5% [−6.7 to 5.0]	–
Nonsurgical management	5 (7.2)	4 (8.9)	16.4% [−8.7 to 11.9]	6 (9.0)	3 (6.4)	−2.7% [−12.7 to 7.3]	4.3% [−10.0 to 18.7]

Group A: January 19–March 15; Group B: March 16–May 11; Group C: September 9–November 5; Group D: November 6–December 31.

Designation of the first wave (Wave 1) at BMC was set as March 15, 2020. This was the initiation of state-mandated stay-at-home restrictions as well as postponement of elective surgeries at our institution. The beginning of the second wave (Wave 2) at BMC was determined to be November 6, 2020, which was the initiation of a second stay-at-home advisory in Massachusetts. Four time-period groups were then created: 8 weeks before (2020 Group A: January 19, 2020–March 15, 2020) and 8 weeks after (2020 Group B: March 16, 2020–May 11, 2020) Wave 1, and 8 weeks before (2020 Group C: September 9, 2020–November 5, 2020) and 8 weeks after (2020 Group D: November 6, 2020–December 31, 2020) Wave 2. We compared 2020 Group A to 2020 Group B as well as 2020 Group C to 2020 Group D to determine change after the course of Wave 1 or Wave 2, respectively. To evaluate whether any potential differences were attributed to COVID-19 and not to temporal or seasonal changes, we compared Groups A, B, C, and D from 2020 to similar time-period groups from 2018 to 2019 (2018/2019 Groups A, B, C, and D). We used the collapsed time periods in 2018 and 2019 to provide more stability in our estimates and increase our power. We additionally compared 2020 Group A and 2020 Group B to 2020 Group C and 2020 Group D to determine any differences between Wave 1 and Wave 2. Variables collected included patient age, sex, ethnicity, body mass index (BMI), comorbidities, American Society of Anesthesiologists score, COVID-19 status, preoperative symptoms, and imaging and laboratory test results. The type of treatment (surgery versus antibiotics), time from presentation until surgery, intraoperative time, postoperative diagnosis, hospital length of stay, and postoperative complications were also collected.

All variables were checked for completeness and plausibility using frequencies (percentage) (categorical) and means/ranges (continuous, ordinal). Descriptive statistics were calculated for all time periods. Univariable statistics between each time period and each independent variable were generated using Fisher exact test (categorical), 1-way analysis of variance (Gaussian), or Kruskal–Wallis equality-of-populations rank test (non-Gaussian). Statistical significance was set at an alpha of 0.05. Logistic regression was used for all outcomes, including demographics and clinical characteristics, different treatment modalities (laparoscopic, open

appendectomy, abdominal washout and drain placement, and antibiotics), as well as different postoperative diagnoses (uncomplicated, acute appendicitis, abscess, perforated appendicitis, and gangrenous appendicitis). We initially estimated absolute differences across each time period and then estimated the difference-in-difference to determine the effect of COVID-19 on our binary outcomes. We used logistic regression to model these relationships using a univariable model. Specifically, for each binary outcome, we initially included binary terms for group and period (2018/2019 vs 2020) and an interaction term between these 2 variables in the model. We then used the Stata post estimation command `-margins-` to estimate the absolute differences between periods, the difference-in-difference, and associated 95% confidence intervals (CIs). Data were analyzed using STATA 16 (StataCorp, College Station, TX).

## RESULTS

A total of 745 patients were admitted to our institution with acute appendicitis during the study period. Our study population consisted of 412 (55%) adult patients and 333 (45%) pediatric patients. In 2018/2019, Group A consisted of 119 patients, Group B consisted of 125 patients, Group C consisted of 147 patients, and Group D consisted of 126 patients. In 2020, Group A consisted of 69 patients, Group B consisted of 45 patients, Group C consisted of 67 patients, and Group D consisted of 47 patients.

Comparison of patient demographics between 2018/2019 and 2020 revealed no statistically significant difference in age, sex, ethnicity, comorbidities, preoperative vitals, preoperative laboratory test results, preoperative characteristics, and postoperative complications.

In regard to modality of treatment, the vast majority of patients underwent laparoscopic appendectomy, and this remained the mainstay of treatment throughout all time periods. There was no statistically significant change in treatment modality when comparing Wave 1 to Wave 2 (Table 1). There was similarly no statistically significant change in treatment modality when comparing Wave 1 (Table 2) or Wave 2 (Table 3) to previous years.

**Table 2**  
Comparison of treatment modalities (Wave 1; 2018/19 vs 2020)

	Baseline time period			COVID time period			Difference in difference (95% CI)
	2018/2019 Group An (%)	2018/2019 Group Bn (%)	Absolute difference (95% CI)	2020 Group An (%)	2020 Group Bn (%)	Absolute difference (95% CI)	
Laparoscopic appendectomy	116 (97.5)	117 (93.6)	−3.8% [−9.0 to 1.2]	63 (91.3)	39 (86.7)	−4.6% [−16.5 to 7.3]	0.7% [−12.2 to 13.7]
Open appendectomy	1 (0.8)	2 (1.6)	0.7% [−1.9 to 3.5]	1 (1.4)	0 (0.0)	–	–
Abdominal washout and drain placement	0 (0.0)	0 (0.0)	–	0 (0.0)	2 (4.4)	–	–
Nonsurgical management	2 (1.7)	5 (4.0)	2.3% [−1.8 to 6.4]	5 (7.2)	4 (8.9)	1.6% [−8.6 to 11.9]	0.6% [−10.4 to 11.7]

Wave 1: period after first initiation of state-mandated stay-at-home restrictions (March 15, 2020); Group A: January 19–March 15; Group B: March 16–May 11.

**Table 3**  
Comparison of treatment modalities (Wave 2; 2018/19 vs 2020)

	Baseline time period			COVID time period			Difference in difference (95% CI)
	2018/2019 Group Cn (%)	2018/2019 Group Dn (%)	Absolute difference (95% CI)	2020 Group Cn (%)	2020 Group Dn (%)	Absolute difference (95% CI)	
Laparoscopic appendectomy	139 (94.6)	116 (92.1)	−2.4% [−8.5 to 3.4]	59 (88.1)	43 (91.5)	−4.2% [−14.4 to 5.9]	−6.7% [−18.5 to 5.1]
Open appendectomy	2 (1.4)	3 (2.4)	1.0% [−2.2 to 4.2]	1 (1.5)	1 (2.1)	0.6% [−4.6 to 5.8]	0.4% [−5.7 to 6.5]
Abdominal washout and drain placement	1 (0.7)	2 (1.6)	1.7% [−1.3 to 4.7]	1 (1.5)	0 (0.0)	−0.9% [−6.7 to 5.0]	2.6% [−4.1 to 9.2]
Nonsurgical management	5 (3.4)	4 (3.2)	−0.1 [−4.8 to 4.6]	6 (9.0)	3 (6.4)	−2.7% [−12.7 to 7.3]	2.6% [−8.4 to 13.7]

Wave 2: period after second initiation of state-mandated stay-at-home restrictions (November 6, 2020); Group C: September 9–November 5; Group D: November 6–December 31.

**Comparison Between Wave 1 and Wave 2 in 2020.** Demographics and clinical characteristics for Wave 1 and Wave 2 are depicted in Table 4. Comparison between the Wave 1 and Wave 2 revealed no significant difference in variables such as the age, sex, ethnicity, and preoperative

laboratory values and vitals. More patients in Wave 1 presented with comorbidities of arrhythmia and chronic obstructive pulmonary disease ( $P = .01$ ). Notably, patients in Group D differed significantly from the other groups in multiple areas, including race, admission heart rate,

**Table 4**  
Patient demographics and characteristics in 2020

Variables	2020 Group A	2020 Group B	2020 Group C	2020 Group D	Total	P value
n (%)	69 (30.3)	45 (19.7)	67 (29.4)	47 (20.6)	228 (100.0)	
Patient characteristics						
Age, median (IQR)	24.0 (34.0)	29.0 (47.5)	19.0 (31.0)	16.0 (35.0)	21.0 (35.5)	.16
Sex, n (%)						
Female, n (%)	28 (40.6)	16 (35.6)	31 (46.3)	21 (44.7)	96 (42.1)	
Male, n (%)	41 (59.4)	29 (64.4)	36 (53.7)	26 (55.3)	132 (57.9)	.69
Race, n (%)						
White, n (%)	60 (88.2)	42 (93.3)	51 (79.7)	31 (67.4)	184 (82.5)	
Black, n (%)	7 (10.3)	2 (4.4)	5 (7.8)	3 (6.5)	17 (7.6)	
Asian, n (%)	0 (0.0)	1 (2.2)	5 (7.8)	1 (2.2)	7 (3.1)	
Comorbidities						
Hypertension, n (%)	12 (17.4)	11 (24.4)	5 (7.5)	11 (23.4)	39 (17.1)	.06
Arrhythmia, n (%)	4 (5.8)	6 (13.3)	0 (0.0)	1 (2.1)	11 (4.8)	.01
COPD, n (%)	0 (0.0)	3 (6.7)	0 (0.0)	0 (0.0)	3 (1.3)	.01
CHF, n (%)	2 (2.9)	1 (2.2)	1 (1.5)	1 (2.1)	5 (2.2)	.95
Kidney disease, n (%)	2 (2.9)	4 (8.9)	0 (0.0)	2 (4.3)	8 (3.5)	.09
Perioperative characteristics						
ASA score, mean (SD)	1.8 (0.7)	2.0 (0.7)	1.8 (0.8)	1.9 (0.8)	1.9 (0.7)	.72
COVID-19 status, n (%)						
Positive, n (%)	0 (0.0)	3 (6.7)	0 (0.0)	1 (2.1)	4 (1.8)	
Intraoperative time (min), mean (SD)	60.4 (32.0)	59.8 (22.9)	62.6 (24.1)	70.6 (32.9)	63.1 (28.5)	.24
Time from presentation until surgery (h), mean (SD)	10.1 (6.3)	8.1 (7.2)	12.3 (10.9)	10.3 (11.6)	10.4 (9.3)	.15
Length of symptoms (h), n (%)						
< 12, n (%)	2 (2.9)	2 (4.4)	6 (9.0)	4 (8.5)	14 (6.1)	
12, n (%)	5 (7.2)	4 (8.9)	8 (11.9)	11 (23.4)	28 (12.3)	
24, n (%)	28 (40.6)	16 (35.6)	21 (31.3)	12 (25.5)	77 (33.8)	
48, n (%)	13 (18.8)	11 (24.4)	14 (20.9)	10 (21.3)	48 (21.1)	
72, n (%)	8 (11.6)	4 (8.9)	4 (6.0)	4 (8.5)	20 (8.8)	
> 72 h, n (%)	13 (18.8)	8 (17.8)	14 (20.9)	6 (12.8)	41 (18.0)	.52
Treatment						
Outcome of appendicitis, n (%)						
Laparoscopic appendectomy, n (%)	63 (91.3)	39 (86.7)	59 (88.1)	43 (91.5)	204 (89.5)	
Open appendectomy, n (%)	1 (1.4)	0 (0.0)	1 (1.5)	1 (2.1)	3 (1.3)	
Abdominal washout and drain placement, n (%)	0 (0.0)	2 (4.4)	1 (1.5)	0 (0.0)	3 (1.3)	
Antibiotics, n (%)	5 (7.2)	4 (8.9)	6 (9.0)	3 (6.4)	18 (7.9)	.72
Length of stay						
Length of stay, mean (SD)	1.6 (1.4)	3.1 (4.0)	2.5 (2.7)	2.7 (3.0)	2.4 (2.8)	.03
Postoperative complications						
Return to OR, n (%)	0 (0.0)	0 (0.0)	0 (0.0)	3 (6.4)	3 (1.3)	.01
Bleeding, n (%)	0 (0.0)	1 (2.3)	0 (0.0)	0 (0.0)	1 (0.4)	.25
Superficial wound infection, n (%)	0 (0.0)	1 (2.3)	0 (0.0)	1 (2.1)	2 (0.9)	.40
Superficial abscess formation, n (%)	0 (0.0)	2 (4.5)	1 (1.5)	0 (0.0)	3 (1.3)	.17
Intra-abdominal abscess formation treated with antibiotics and/or IR, n (%)	1 (1.5)	2 (4.5)	6 (9.0)	4 (8.5)	13 (5.8)	.23
Discharge disposition, n (%)						
Home, n (%)	67 (98.5)	44 (97.8)	67 (100.0)	47 (100.0)	225 (99.1)	
Rehab, n (%)	1 (1.5)	1 (2.2)	0 (0.0)	0 (0.0)	2 (0.9)	.53

Group A: January 19–March 15; Group B: March 16–May 11; Group C: September 9–November 5; Group D: November 6–December 31. ASA, American Society of Anesthesiologists; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; IQR, interquartile range; IR, interventional radiology; OR, operating room.

**Table 5**  
Comparison of postoperative diagnosis in 2020

	Baseline time period		Absolute difference (95% CI)	COVID time period		Absolute difference (95% CI)	Difference in difference (95% CI)
	Group A n (%)	Group Bn (%)		Group Cn (%)	Group Dn (%)		
Uncomplicated acute appendicitis	57 (82.6)	18 (40.0)	−42.6% [−59.4 to −25.7]	50 (74.6)	30 (63.8)	−10.8% [−28.0 to 6.4]	−31.8 [−55.9 to −7.7]
Abscess	3 (4.3)	8 (17.8)	13.4% [1.3–25.6]	4 (6.0)	5 (10.6)	4.7% [−5.8 to 15.1]	8.8% [−7.3 to 24.8]
Perforated appendicitis	10 (14.5)	16 (35.6)	21.1% [4.8–37.3]	17 (25.4)	15 (31.9)	6.5% [−10.4 to 23.4]	14.5% [−8.9 to 37.9]
Gangrenous appendicitis	5 (7.2)	14 (31.1)	23.8% [9.0–38.7]	0 (0.0)	8 (17.0)	17.0% [no CI available]	–

Group A: January 19–March 15; Group B: March 16–May 11; Group C: September 9–November 5; Group D: November 6–December 31.

and incidence of return to the operating room. Duration of the procedure, other postoperative complications, and length of admission were similar between Wave 1 and Wave 2. The trend of uncomplicated acute appendicitis diagnoses decreasing and perforated appendicitis and gangrenous appendicitis diagnoses increasing persisted in the Wave 2 data similar to Wave 1. However, although there was a statistical significance in the trend of diagnoses between Group A and Group B, there was no statistical significance in the trend of diagnoses between Group C and Group D. When comparing the decrease in uncomplicated acute appendicitis incidence across Wave 1 (Group A versus Group B) and across Wave 2 (Group C versus Group D), there was a significantly less decrease during Wave 2 (−31.8, CI: −55.9 to −7.7). The increase in incidence of abscess and perforated appendicitis was similarly less prominent in Wave 2, but these did not reach statistical significance. The difference in difference calculation could not be completed for gangrenous appendicitis because of the lack of patients with this diagnosis in Group C. However, the trend was similar, with an increase in gangrenous appendicitis between Group C and Group D, but less prominent than across Group A and Group B (Table 5).

**Comparison of Wave 1 Between 2018/2019 and 2020.** In 2020 Group A, 57 patients (82.6%) had uncomplicated acute appendicitis compared to only 18 (40.0%) in 2020 Group B. This was statistically significant (−42.6%, CI: −59.4 to −25.7). Simultaneously, there was a statistically significant increase in postoperative diagnosis of perforated appendicitis (21.0%, CI: 4.7–37.3) and gangrenous appendicitis (23.8%, CI: 9.0–38.7). During the 2018/2019 time period, there were no change in incidence of uncomplicated acute appendicitis (−2.0%, CI: −11.8 to 7.7), a slight increase in perforated appendicitis (3.9%, CI: −4.6 to 12.4), and a slight decrease in gangrenous appendicitis (4.3%, CI: −10.1 to 1.4). None of these differences were statistically significant. When comparing 2020 Groups A and B to 2018/2019 Groups A and B, there was a statistically significant difference in the decrease of uncomplicated acute appendicitis diagnoses in 2020 compared to 2018/2019 (−40.5%, CI: −60.0 to −21.0), with

a statistically significant difference in the increase of gangrenous appendicitis diagnoses (28.2%, CI: −12.2 to 44.1) during the same time periods (Table 6).

**Comparison of Wave 2 Between 2018/2019 and 2020.** In 2020 Group C, 50 patients (74.6%) had uncomplicated acute appendicitis compared to 30 patients (63.8%) in Group D. This difference was not statistically significant (−10.8%, CI: −28.0 to 6.4). There was a decrease of perforated appendicitis diagnoses in this time period (−6.5%, CI: −23.4 to 10.3). Diagnosis of gangrenous appendicitis increased from 0 patient in 2020 Group C to 8 patients (17.0%) in 2020 Group D. However, statistical significance of this change could not be calculated because of the lack of patients in Group C. In the corresponding 2018/2019 groups, the diagnosis of uncomplicated acute appendicitis, abscess, perforated appendicitis, and gangrenous appendicitis did not change significantly between Groups C and D. There was no statistical significance in the decrease of uncomplicated acute appendicitis diagnoses in 2020 compared to 2018/2019 (−11.8%, CI: −32.2 to 8.6), nor was there a statistically significant difference in the increase in perforated appendicitis diagnoses (7.3%, CI: −12.3 to 27.0) (Table 7).

## DISCUSSION

To our knowledge, this is the first study which analyzes the long-term effect of the COVID-19 pandemic on the severity of acute appendicitis. We identified a decrease in uncomplicated acute appendicitis and an increase in complicated disease in both Wave 1 and Wave 2 of the COVID-19 pandemic. Overall, the differences seen in Wave 2 at our institution were similar to those seen in Wave 1 but less prominent and not statistically significant. The fact that the changes in Wave 1 were significantly different when compared to previous years suggests that the COVID-19 pandemic and the social restrictions associated with it may have contributed to the severity of acute appendicitis seen at our institution [2]. This trend continued during Wave 2.

**Table 6**  
Comparison of postoperative diagnosis (Wave 1; 2018/19 vs 2020)

	Baseline time period		Absolute difference (95% CI)	COVID time period		Absolute difference (95% CI)	Difference in difference (95% CI)
	2018/2019 Group A n (%)	2018/2019 Group Bn (%)		2020 Group An (%)	2020 Group Bn (%)		
Uncomplicated acute appendicitis	97 (82.9)	97 (80.8)	−2.0% [−11 to 8,7.7]	57 (82.6)	18 (40.0)	−42.6% [−59.4 to −25.7]	−40.5% [−60.0 to −21.0]
Abscess	1 (0.9)	6 (5.0)	4.1% [−0.01 to 8.3]	3 (4.3)	8 (17.8)	13.4% [1.2–25.6]	9.2% [−3.5 to 22.1]
Perforated appendicitis	13 (11.1)	18 (15.0)	3.9% [−4.6 to 12.4]	10 (14.5)	16 (35.6)	21.0% [4.7–37.3]	17.1% [−1.2 to 35.5]
Gangrenous appendicitis	9 (7.7)	4 (3.3)	−4.3% [−10.1 to 1.4]	5 (7.2)	14 (31.1)	23.8% [9.0–38.7]	28.2% [−12.2 to 44.1]

Wave 1: period after first initiation of state-mandated stay-at-home restrictions (March 15, 2020); Group A: January 19–March 15; Group B: March 16–May 11.



**Table 7**  
Comparison of postoperative diagnosis (Wave 2; 2018/19 vs 2020)

	Baseline time period		Absolute difference (95% CI)	COVID time period		Absolute difference (95% CI)	Difference in difference (95% CI)
	2018/2019 Group C n (%)	2018/2019 Group Dn (%)		2020 Group Cn (%)	2020 Group Dn (%)		
Uncomplicated acute appendicitis	102 (69.4)	88 (70.4)	−1.0% [−11.9 to 9.9]	50 (74.6)	30 (63.8)	−10.8% [−28.0 to 6.4]	−11.8% [−32.2 to 8.6]
Abscess	4 (2.7)	7 (5.6)	2.8% [−1.9 to 7.6]	4 (6.0)	5 (10.6)	4.6% [−5.8 to 15.2]	−1.8% [−13.3 to 9.6]
Perforated appendicitis	35 (23.8)	29 (23.0)	−0.7% [−10.8 to 9.2]	17 (25.4)	15 (31.9)	−6.5% [−23.4 to 10.3]	7.3% [−12.3 to 27.0]
Gangrenous appendicitis	9 (6.1)	7 (5.6)	−0.5% [−6.1 to 5.0]	0 (0.0)	8 (17.0)	17.0% [no CI available]	–

Wave 2: period after second initiation of state-mandated stay-at-home restrictions (November 6, 2020); Group C: September 9–November 5; Group D: November 6–December 31.

There are various plausible reasons that could explain our results. The fear of contracting COVID-19 by seeking in-hospital medical care remains high despite the possibility of an emergent clinical issue such as appendicitis [5]. In a recent report, Gale et al reported that 25.5% of surveyed individuals confronted with a hypothetical scenario consistent with appendicitis prioritized avoidance of COVID-19 exposure in the emergency room over seeking appropriate medical attention [6]. Delayed care-seeking behavior was similarly evident in a study from the Netherlands, which found that patients were motivated by fear of contamination, limited access to services, and stay-at-home instructions from referring professionals [7]. The trend was also noted during the second wave of the COVID-19 pandemic which occurred in the latter part of 2020 [8]. This is in accordance with our results indicating that the increase in complicated appendicitis during Wave 2 could be attributed to the persistent fear of contracting COVID-19.

This finding is significant given the fact that new strategies were developed during the first wave to quickly address a variety of issues that impacted the surgical practice. However, the acquisition of abundant personal protective equipment, development of protocols for COVID screening and testing, as well as appropriate redeployment of staff and creation of dedicated COVID-19 hospital units [9] appeared to be unsuccessful in assuring the patients regarding the safety of presenting to the hospital and seeking care in a timely fashion.

In our cohort, we identified a statistically significant difference in uncomplicated acute appendicitis patients between Wave 1 and Wave 2. One potential explanation for this finding could be the fact that many of the most severe COVID-19–related restrictions in Massachusetts were relaxed during the second half of 2020. For example, the stay-at-home advisory implemented on November 6, 2020, specified that Massachusetts residents should self-isolate between the hours of 10 PM and 5:30 AM, except for essential services. In comparison, during Wave 1, the stay-at-home advisory stressed self-isolation at all times for a 2-week period [4]. This change may reflect an increased availability of services such as transportation and in-person primary care appointments for patients to use during Wave 2.

A recent report by Scheijmans et al documents an analysis of patients presenting with acute appendicitis in 19 institutions in the Netherlands during the first wave of COVID-19. They reported a decrease of incidence of uncomplicated appendicitis and an increase of complicated disease compared to a similar period in 2019 [10]. This is consistent with our findings. Moreover, we were able to demonstrate that the same trend occurred for the second wave when comparing 2020 to the previous 2 years.

With the recent increase of new COVID-19 cases secondary to the delta variant, it is vitally important to learn from our experiences with the previous waves of the pandemic. In addition to creating protocols that address the need for enhancement of surgical services in the pandemic era, emphasis should also be given in developing effective communication strategies to the patients. Social media platforms, establishment of hospital hotlines, and video presentations in hospital

websites can potentially be used to educate patients and communicate to them that they are safe to seek emergent surgical attention when necessary. Also, utilization and optimization of the telemedicine tools can offer the patients the opportunity to consult their surgeons in a more timely fashion. These measures could provide a solution that might not only prevent worsening of patient disease burden but also ease the strain on hospital systems during a global pandemic.

This study has several limitations. This is a retrospective analysis with a relatively small volume of cases at a singular institution. The changes seen in this small of a cohort may not accurately reflect the larger population. A bigger cohort may also provide the power needed to determine statistical significance of the trends we identified. Additionally, the dates chosen to represent Wave 1 and Wave 2 were based on information particular to the state of Massachusetts. The date of Wave 2, especially, was highly variable depending on geographic location in the United States and throughout the world. For example, in a report by Iftimie et al, the second wave of infections was determined to take place in the 3½ months after July 1, 2020 [11]. Although it is our belief that stay-at-home restrictions and subsequent delayed access to health care are the major reason for our reported results, a difference in selected dates could have altered our findings. Finally, our analysis was performed using ICD codes to identify patients with the diagnosis of uncomplicated and complicated acute appendicitis. However, it is possible that some patients might not have been captured in our cohort.

In conclusion, the severity of acute appendicitis at our institution increased during Wave 2 of the COVID-19 pandemic, similar to in Wave 1. The overall incidence of uncomplicated acute appendicitis decreased and the incidence of complicated appendicitis increased during both Waves 1 and 2 when compared to 2018 and 2019.

### Author Contribution

Elizabeth Santone: Methodology, Investigation, Writing – original draft; Francesca Izzo: Investigation; Karina Lo: Investigation; Aixa M. Pérez Coulter: Formal analysis; Nicolas Jabbour: Supervision; Georgios Orthopoulos: Conceptualization, Methodology, Writing – reviewing & editing.

### Conflict of Interest

The authors have no conflicts of interest to declare.

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## Ethics Approval

The protocol for this study was approved by the Baystate Medical Center Institutional Review Board.

## Appendix A. International Classification of Diseases (ICD)-10 codes for acute appendicitis

Acute appendicitis K35->

- K35 Acute appendicitis
- K35.2 Acute appendicitis with generalized peritonitis
- K35.20 ... without abscess
- K35.21 ... with abscess
- K35.3 Acute appendicitis with localized peritonitis
- K35.30 ... without perforation or gangrene
- K35.31 ... and gangrene, without perforation
- K35.32 Acute appendicitis with perforation and localized peritonitis, without abscess
- K35.33 Acute appendicitis with perforation and localized peritonitis, with abscess
- K35.8 Other and unspecified acute appendicitis
- K35.80 Unspecified acute appendicitis
- K35.89 Other acute appendicitis
- K35.890 ... without perforation or gangrene
- K35.891 ... without perforation, with gangrene

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