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Original Research

Effect of government-issued state of emergency and reopening orders on cardiovascular hospitalizations during the COVID-19 pandemic

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ABSTRACT

Objective: Little is known about the effect of government-issued State of Emergency (SOE) and Reopening orders on health care behaviors. We aimed to determine the effect of SOE and Phase 1 of Reopening orders on hospitalizations for acute myocardial infarction (AMI) or acute decompensated heart failure (ADHF).

Methods: Hospitalizations for AMI and ADHF in the UNC Health system, which includes 10 hospitals in both urban and rural counties, were identified. An interrupted time series design was used to compare weekly hospitalization rates for eight weeks before the March 10th SOE declaration, eight weeks between the SOE order and Phase 1 of Reopening order, and the subsequent eight weeks.

Results: Overall, 3,792 hospitalizations for AMI and 7,223 for ADHF were identified. Rates before March 10th were stable. AMI/ADHF hospitalizations declined about 6% per week in both urban and rural hospitals from March 11th to May 5th. Larger declines in hospitalizations were seen in adults ≥65 years old (-8% per week), women (-7% per week), and White individuals (-6% per week). After the Reopening order, AMI/ADHF hospitalizations increased by 8% per week in urban centers and 9% per week in rural centers, including a significant increase in each demographic group. The decline and rebound in acute CV hospitalizations were most pronounced in the two weeks following the government orders.

Conclusions: AMI and ADHF hospitalization rates closely correlated to SOE and Reopening orders. These data highlight the impact of public health measures on individuals seeking care for essential services; future policies may benefit from clarity regarding when individuals should present for care.

1. Introduction

An unexpected decline in rates of hospitalizations for a broad range of cardiovascular conditions has been observed worldwide during the coronavirus disease-2019 (COVID-19) pandemic [1–8]. The etiology for this remains unclear with proposed etiologies including patient fears of developing COVID-19 in the hospital setting, decreased air pollution, increased sleep duration, and less work-related stress. Government issued stay at home orders have been shown to affect elective procedures [9,10], but it is unclear if these mandates affected patients seeking emergency care.

The first person to test positive for coronavirus in North Carolina (NC) was in Raleigh on March 3, 2020. On March 9, there were 6 confirmed cases of COVID-19 in Wake County and 7 in the state. The next day, the Governor issued a State of Emergency (SOE) order to coordinate responses to COVID [11]. On March 14, K-12 schools were closed and on March 17, 2020, restaurants and bars were closed. All elective and

Abbreviations: COVID-19, Coronavirus disease 2019; CV, cardiovascular; UNC, University of North Carolina; AMI, acute myocardial infarction; ADHF, acute decompensated heart failure; SARS-COV-2, Severe Acute Respiratory Syndrome-Coronavirus 2.

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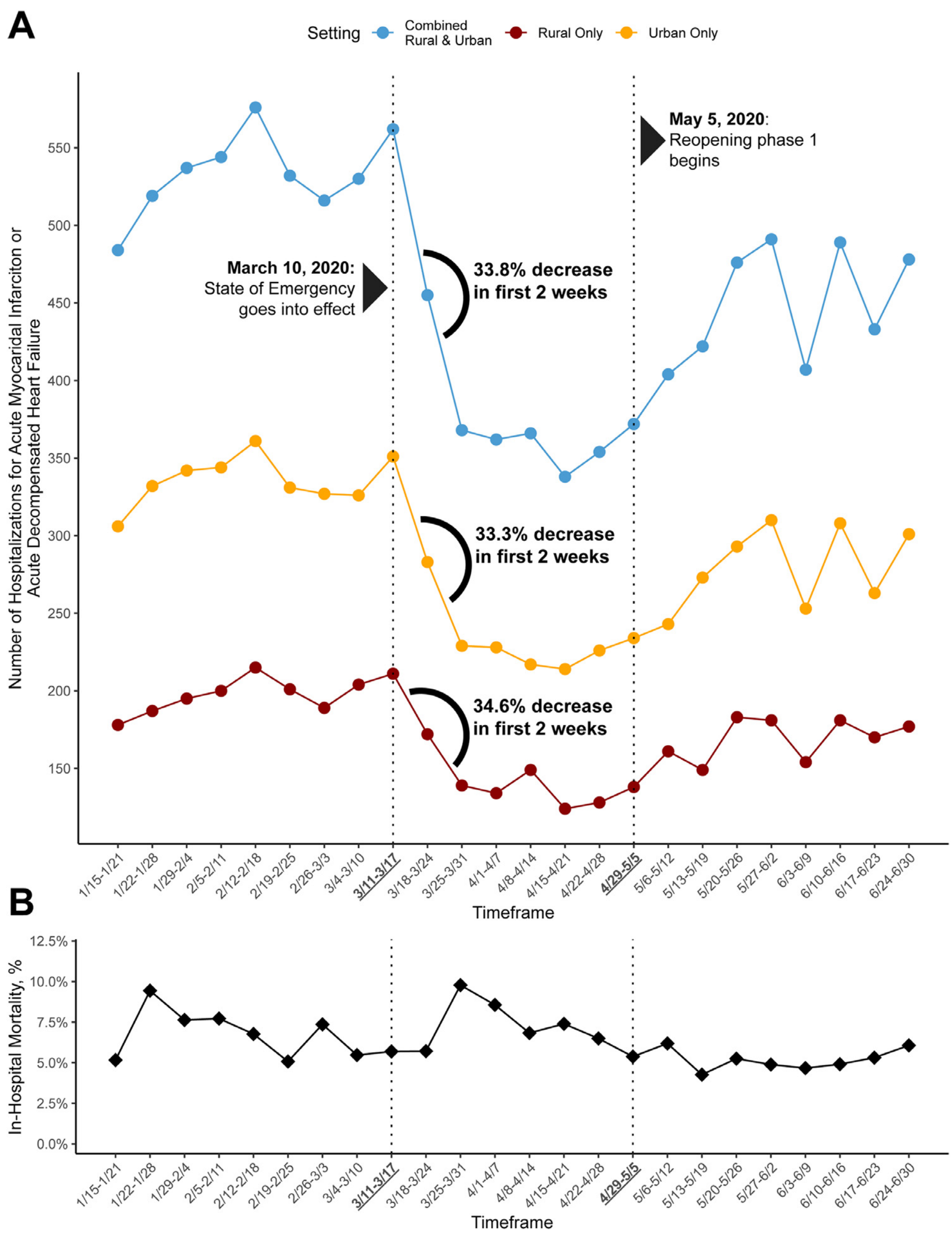
Central illustration



non-urgent surgeries and procedures were suspended by order of the Department of Health and Human Services as of March 23. On March 27, the Governor ordered NC residents to stay at home for 30 days. On that day, there were 232 confirmed cases of COVID-19 in NC. On May 5, the Governor announced that NC would enter Phase 1 of Reopening on May 8 which would permit the reopening of 'nonessential' businesses (e.g. clothing and hardware stores), worship centers, parks and child-care facilities and allow people to leave their homes for commercial purposes.

While much remains unknown about COVID-19, older adults and certain racial/ethnic populations disproportionately account for more severe COVID-19 illnesses and deaths [12–14]. It is also apparent that the disease has disproportionately impacted urban areas [15,16]. Therefore, there may be variation in perception of exposure risk to Severe Acute Respiratory Syndrome-Coronavirus 2 (SARS-COV-2) which may have a differential effect on the trends in hospitalizations in urban versus rural hospitals and across demographic groups. The University of North Carolina (UNC) Health system spans the state of NC and includes 11 hospitals equitably distributed throughout urban and rural areas; it serves the diverse population of NC, which is 28% rural and 22% Black [17]. Each of these hospitals is well equipped to provide care for patients who may need acute CV care such as acute myocardial infarction (AMI) or acute decompensated heart failure (ADHF). The unique geography of the state of NC and the distribution of UNC hospitals throughout the state provided an opportunity to examine the effect of government issued orders in NC.

2. Methods

Hospitalizations containing a hospital billed discharge diagnosis of acute CV conditions of interest with a primary discharge date between January 15th, 2020 and June 30th, 2020 at inpatient care entities across the UNC Health system were retrospectively examined. Hospitalizations were categorized according to International Classification of Diseases, Tenth Revision (ICD-10) coding into the following categories: AMI, ADHF, and cardiac arrest using the Informatics for Integrating Biology and the Bedside Platform (i2b2) (Supplemental Table 1). UNC Health system began recording COVID-19 data in its centers on March 12th

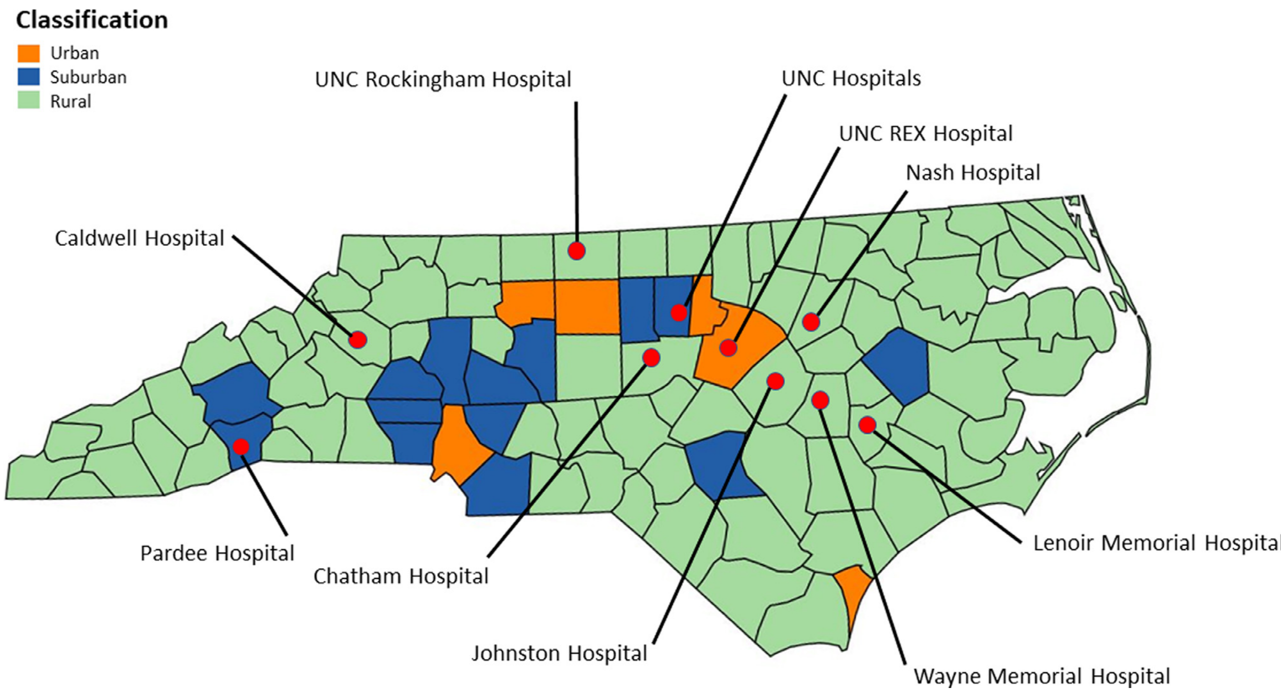


Fig. 1. Hospitals in the University of North Carolina Health System that were included in this study. Of the ten hospitals, seven are in rural counties based on the population densities collected by the North Carolina Rural Center.

(Central illustration and supplemental figure 1). i2b2 is the flagship tool developed by the i2b2 Center, in the North Carolina Translational & Clinical Sciences Institute (NC TraCS) [18]. i2b2 provides a way for researchers to query the Carolina Data Warehouse for Health, a central data repository containing clinical, research, and administrative data sourced from the UNC Health System. Researchers can apply criteria for patient demographics, encounter information, ICD-9-CM and ICD-10-CM diagnoses, ICD-9-CM/ICD-10-CM/CPT/HCPCS procedure codes, vitals, laboratory results, discharge disposition, and medications. To protect patient information, i2b2 does not report frequencies <10; we used 9 as an estimate when values were suppressed. The i2b2 at the University of North Carolina is supported by the National Center for Advancing Translational Sciences (NCATS), National Institutes of Health, through Grant Award Number UL1TR002489.

There are 100 counties in NC of which 80 counties were identified as rural, 14 as suburban, and 6 as urban based on the population densities derived from 2014 estimates of the 2010 U.S Census population by the NC Rural Center [19]. Data were available for 10 of 11 UNC health system hospitals (Onslow Memorial Hospital was acquired in 2019 and was not reporting to i2b2 at the date of data collection); these hospitals were categorized into urban, suburban, or rural based on the county in which they were located (Fig. 1). For this study, we collapsed the urban and suburban counties into one analytic category and compared with rural counties. Urban/suburban hospitals included UNC Medical Center, UNC REX Hospital, and Pardee Hospital. Rural hospitals included Caldwell Hospital, Chatham Hospital, Johnston Hospital, Lenoir Memorial Hospital, Nash Hospital, UNC Rockingham Hospital, and Wayne Memorial Hospital (Fig. 1). This study was considered exempt from institutional review board approval as i2b2 contains only deidentified information.

Demographics and clinical characteristics including age, sex, race, diabetes mellitus, and hypertension, chronic obstructive pulmonary disease, discharge disposition, and length of stay data were collected. To account for the large daily variation in hospital volume during the pandemic, weekly rates of acute CV diagnoses of interest were calculated. Age was categorized as ≥65 years and <65 years old. To examine the impact of COVID-19 on trends in CV hospitalizations, we utilized an interrupted time series (ITS) design and segmented log-linear negative binomial regression. The ITS design is a quasi-experimental approach and considered one of the strongest methods for evaluating longitudinal effects of interventions [20,21]. Briefly, the study period is divided into pre-intervention and post-intervention segments, and separate regression analyses are built for each period. Using ITS, we then compared both the immediate impact (intercepts) and weekly trends (slopes) from the eight weeks before March 10th, 2020 (January 15th–March 10th) to the eight weeks after (March 11th–May 5th), and then the eight weeks after March 10th to the following eight weeks (May 6th–June 30th) during reopening. In-hospital mortality and cardiac arrest were also examined using similar methods. Categorical variables were compared using Chi-square tests and continuous variables were compared using Kruskal Wallis test, as appropriate. All analyses were done using SAS version 9.4 (SAS Inc, Cary, NC) and R version 4.0.0 (2020, R Core Team, Vienna, Austria).

3. Results

A total of 11,015 hospitalizations for AMI or ADHF were identified from January 15, 2020 to June 30, 2020 in the UNC Health system, including 3792 for AMI (34%) and 7223 for ADHF (66%). A breakdown showed that 6895 (63%) occurred at hospitals in urban counties, 5943 (54%) were men, 7099 (64%) were White, 3372 (31%) were Black, and 7064 (64%) were 65 years or older.

There were 1462 AMI and 2776 ADHF admissions in the eight weeks preceding the SOE declaration in NC (January 15th to March 10th), compared to 1089 AMI and 2088 ADHF admissions from March 11th to May 5th, and 1241 AMI and 2359 ADHF admissions from May 6th to June 30th (Table 1, Fig. 2). Incident rate ratios (IRR) representing average weekly AMI/ADHF hospitalizations during the three time intervals in our study are displayed in Table 2, stratified by hospital location and demographic group. Between January 15th and March 10th, there were an average of 512 (95% CI 457, 574) AMI or ADHF hospitalizations per week at centers in the UNC Health system, and trends were stable (IRR 1.01 95% CI 0.99, 1.03, p = 0.52). Following the March 10th SOE declaration, there was a 33.8% drop in AMI/AHDF hospitalizations from March 11th through March 24th which then stabilized. Overall admissions for AMI

Table 1
Characteristics of Patients Hospitalized for acute myocardial infarction (AMI) or acute decompensated heart failure (ADHF), January 15, 2020 to June 30, 2020.

	January 15, 2020–March 10, 2020	March 11, 2020–May 5, 2020	P(2-sided)[a]	May 6, 2020–June 30, 2020	P(2-sided)[b]
AMI/ADHF hospitalizations, n	4238	3177	–	3600	–
Urban Center, n (%)	2669 (63)	1982 (62)	0.60	2244 (62)	0.96
Rural Center, n (%)	1569 (37)	1195 (38)		1356 (38)	
Age ≥ 65 years, n (%)	2855 (67)	1967 (62)	<0.0001	2242 (62)	0.77
Men, n (%)	2328 (55)	1671 (53)	0.05	1944 (54)	0.25
Race, n (%)					
White	2830 (67)	1976 (62)	0.0004	2293 (64)	0.20
Black	1223 (29)	1008 (32)	0.007	1141 (32)	0.98
Other	185 (4)	193 (6)	0.0009	166 (5)	0.007
Diabetes Mellitus[c]	1416 (33)	1001 (32)	0.08	1095 (30)	0.33
Hypertension[d]	2354 (56)	1686 (53)	0.03	1861 (52)	0.26
Chronic Obstructive Pulmonary Disease[e]	1106 (26)	783 (25)	0.16	805 (22)	0.03
Length of Stay > 2 days	1790 (42)	1325 (42)	0.65	1451 (40)	0.24
Discharge to Skilled Nursing Facility	786 (19)	470 (15)	<0.0001	514 (14)	0.55
In-hospital Mortality, n (%)	290 (7)	218 (7)	0.97	187 (5)	0.004
Cardiac Arrest	207 (32)	216 (34)	–	216 (34)	–

[a] chi-square test comparing January 15th–March 10th to March 11th–May 5th.
[b] chi-square test comparing March 11th–May 5th to May 6th–June 30th.
[c] Identified with ICD-10-CM codes: E08, E09, E10, E11, E13.
[d] Identified with ICD-10-CM codes: I10, I11, I16.
[e] Identified with ICD-10-CM codes: J41, J42, J43, J44.

Table 2
Trends estimates for AMI or ADHF admissions, stratified by hospital location, age, sex, and race.

	January 22, 2020–March 10, 2020 IRR (95% CI)[a]	March 11, 2020–April 28, 2020 IRR (95% CI)[a]	p-value[b]	April 29, 2020–June 16, 2020 IRR (95% CI)[a]	*p*-value[c]
AMI or ADHF	1.01 (0.99, 1.03)	0.95 (0.93, 0.97)	0.0002	1.08 (1.04, 1.12)	<0.0001
Urban	1.00 (0.98, 1.03)	0.95 (0.92, 0.97)	0.001	1.07 (1.03, 1.12)	0.0001
Rural	1.01 (0.99, 1.04)	0.94 (0.92, 0.96)	<0.0001	1.09 (1.05, 1.14)	<0.0001
Age < 65 years	1.02 (0.98, 1.06)	0.98 (0.94, 1.01)	0.09	1.08 (1.02, 1.15)	0.02
Age ≥ 65 years	1.00 (0.98, 1.02)	0.93 (0.90, 0.95)	<0.0001	1.08 (1.04, 1.13)	<0.0001
Men	1.01 (0.98, 1.03)	0.96 (0.94, 0.99)	0.007	1.08 (1.03, 1.12)	0.0002
Women	1.01 (0.98, 1.04)	0.93 (0.90, 0.96)	0.0004	1.08 (1.02, 1.14)	0.002
White	1.01 (0.99, 1.03)	0.94 (0.92, 0.96)	<0.0001	1.09 (1.05, 1.13)	<0.0001
Black	1.00 (0.97, 1.03)	0.96 (0.93, 0.99)	0.09	1.07 (1.01, 1.13)	0.003
AMI	1.00 (0.98, 1.02)	0.96 (0.94, 0.99)	0.04	1.04 (1.00, 1.09)	0.03
Urban	0.99 (0.97, 1.02)	0.96 (0.93, 0.99)	0.10	1.04 (0.99, 1.10)	0.04
Rural	1.01 (0.98, 1.05)	0.97 (0.93, 1.02)	0.17	1.04 (0.97, 1.12)	0.32
Age < 65 years	1.02 (0.97, 1.07)	1.02 (0.97, 1.07)	0.96	1.05 (0.96, 1.14)	0.44
Age ≥ 65 years	0.99 (0.96, 1.02)	0.93 (0.90, 0.96)	0.005	1.04 (0.99, 1.10)	0.03
Men	0.99 (0.96, 1.03)	0.97 (0.93, 1.01)	0.38	1.07 (1.00, 1.14)	0.008
Women	1.01 (0.97, 1.05)	0.95 (0.92, 0.99)	0.04	1.01 (0.94, 1.07)	0.93
White	1.00 (0.97, 1.02)	0.96 (0.93, 0.99)	0.07	1.03 (0.98, 1.08)	0.15
Black	1.03 (0.99, 1.08)	0.98 (0.93, 1.02)	0.08	1.10 (1.01, 1.19)	0.07
ADHF	1.01 (0.98, 1.04)	0.94 (0.91, 0.96)	0.0001	1.10 (1.05, 1.15)	<0.0001
Urban	1.01 (0.98, 1.04)	0.94 (0.91, 0.97)	0.001	1.09 (1.04, 1.15)	0.0002
Rural	1.01 (0.99, 1.04)	0.92 (0.90, 0.95)	<0.0001	1.12 (1.06, 1.17)	<0.0001
Age < 65 years	1.02 (0.98, 1.06)	0.95 (0.92, 0.99)	0.02	1.10 (1.03, 1.18)	0.0007
Age ≥ 65 years	1.01 (0.98, 1.03)	0.93 (0.90, 0.95)	<0.0001	1.10 (1.05, 1.16)	<0.0001
Men	1.01 (0.99, 1.04)	0.95 (0.92, 0.98)	0.004	1.08 (1.03, 1.14)	0.004
Women	1.01 (0.97, 1.04)	0.92 (0.89, 0.96)	0.0008	1.12 (1.05, 1.19)	0.0001
White	1.02 (0.99, 1.05)	0.93 (0.90, 0.96)	<0.0001	1.12 (1.07, 1.17)	<0.0001
Black	0.98 (0.94, 1.02)	0.95 (0.91, 0.99)	0.28	1.06 (0.98, 1.14)	0.02

Abbreviations: IRR, incidence rate ratio; CI, confidence interval; AMI, acute myocardial infarction; ADHF, acute decompensated heart failure.
[a] Average weekly change in slopes estimated using interrupted times series design and segmented log-linear negative binomial model.
[b] Wald Chi-square test comparing weekly trend before and after the declaration of state of emergency in NC (March 10, 2020).
[c] Wald Chi-square test comparing weekly trend before and after April 28, 2020.

or ADHF declined by about 6% per week in the 8 weeks after the SOE order (change in intercept $p = 0.32$, change in slope $p = 0.0002$). In the first three weeks during Phase 1 of Reopening, there was a substantial increase in rates of hospitalization for AMI or ADHF which then stabilized; overall rates increased by 8% per week during the 8 weeks after reopening (change in intercept $p = 0.0009$, change in slope $p < 0.0001$, Central Illustration, panel A).

In-hospital mortality among AMI/ADHF patients remained relatively unchanged at about 6% (Central Illustration, panel B). Hospital admissions for cardiac arrest remained unchanged over the entire study period (26 in the first week to 33 in the final week; change in first intercept $p = 0.77$, change in first slope $p = 0.53$; change in second intercept $p = 0.49$, change in second slope $p = 0.77$).

Before March 10th, urban centers accounted for 328 (95% CI 291, 370) and rural centers accounted for 184 (95% CI 165, 206) weekly hospitalizations for AMI or ADHF and trends for both were stable during this time (IRR 1.00, 95% CI 0.98, 1.03, $p = 0.77$ and IRR 1.01 95% CI 0.99, 1.04, $p = 0.22$, respectively). In the eight weeks after March 10th, AMI or ADHF hospitalizations declined by about 6% each week in both urban and rural centers (Urban: change in intercept $p = 0.34$,

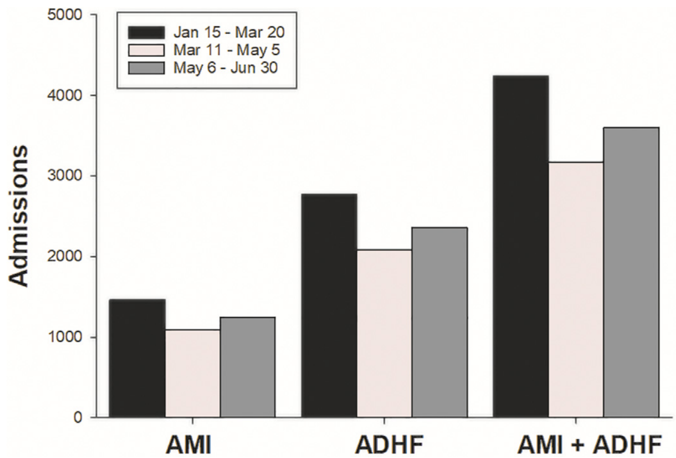


Fig. 2. Hospitalizations in the UNC Health System for acute myocardial infarction (AMI) or acute decompensated heart failure (ADHF) in 8 weeks before the SOE order, 8 weeks between SOE order and Phase 1 reopening and then 8 weeks after reopening.

change in slope $p = 0.001$; Rural: change in intercept $p = 0.47$, change in slope $p < 0.0001$, Table 2, Central Illustration). A similarly expeditious decline in AMI or AHDF hospitalizations in the first two weeks after the SOE declaration was seen in urban (33.3%) and rural (34.6%) hospitals alike. After reopening measures were implemented in May, AMI or ADHF hospitalizations increased by 8% per week in urban centers (change in intercept $p = 0.003$, change in slope $p = 0.0001$) and 9% per week in rural centers (change in intercept $p = 0.0005$, change in slope $p<0.0001$, Table 2), despite increases in COVID-19 cases (Supplemental Figure 1).

Compared to the same dates in 2019, there were 14% fewer AMI hospitalizations (1089 vs 1265) and 24% fewer ADHF hospitalizations (2088 vs 2741) from March 10th to May 5th, 2020. Hospitalizations at urban centers in 2020 were down 20% for AMI and 26% for ADHF compared to 2019. Rural centers had similar AMI volumes but were down 21% in ADHF hospitalizations. In 2019, admissions for AMI or ADHF were stable in the time matched eight weeks before March 10th (IRR 0.98, 95% CI 0.95, 1.02, $p = 0.33$, and IRR 0.99, 95% CI 0.97, 1.02, $p = 0.54$, respectively), in the eight weeks following March 10th (AMI: change in intercept $p = 0.83$, change in slope $p = 0.23$; ADHF: change in intercept $p = 0.98$, change in slope $p = 0.45$), and in the next eight weeks (AMI: change in intercept $p = 0.20$, change in slope $p = 0.70$; ADHF: change in intercept $p = 0.01$, change in slope $p = 0.22$).

Between January 15th and March 10th, hospitalization rates for AMI or ADHF were stable for all groups that were analyzed (Table 2). In the eight weeks after March 10th, relatively large declines in hospitalizations were seen in adults ≥65 years old (−8% per week, change in intercept $p = 0.43$, change in slope $p < 0.0001$), women (−7% per week, change in intercept $p = 0.67$, change in slope $p = 0.0004$), and White adults (−6% per week, change in intercept $p = 0.05$, change in slope $p < 0.0001$). Smaller declines were seen in men (−4% per week, change in intercept $p = 0.03$, change in slope $p = 0.007$) with non-statistically significant declines seen in Black adults (−4% per week, change in intercept $p = 0.98$, change in slope $p = 0.09$) and individuals <65 years old (−3% per week, change in intercept $p = 0.48$, change in slope $p = 0.09$). After reopening, significant increases were observed in rates of AMI or ADHF hospitalizations in all groups including White adults, Black adults, young adults, older adults, men, and women (Table 2, Fig. 3).

4. Discussion

In this analysis investigating the temporal trends in acute CV hospitalizations in a North Carolina hospital system, we found a rapid and significant decline in AMI/ADHF hospitalizations following the SOE declaration (March 10th, 2020). This affected both urban and rural hospitals in NC despite a disproportionate distribution of COVID-19 cases in urban areas [16], with older adults experiencing the most substantial declines. AMI/ADHF hospitalizations rapidly rebounded after Phase 1 Reopening was announced, even with a continued increase in COVID-19 cases. These data highlight the temporal relationship of government orders and acute CV hospitalizations in both urban and rural hospitals during the COVID-19 pandemic.

Our data are consistent with recent observational analyses from the United States that reported a significant decline in hospitalizations from CV disease [1,4,7,8]. Several potential explanations for the observed declines in AMI or ADHF hospitalizations have been proposed which can be divided into two large categories: reduction in the actual occurrence of AMI/ADHF and changes in patient behavior so that they fail to seek medical care.

Potential etiologies for reduced occurrence of AMI/ADHF include better self-care such as improved dietary compliance and adherence to medical therapy in those with heart failure with the purpose of avoiding contact with the medical system due to perceived risk of exposure to SARS-COV2 [22]. Physical isolation can also prevent exposure to infectious triggers of ADHF. Decreased fast-food intake, improved sleep hygiene and reduced exposure to air pollution may also contribute to a lower risk of AMI/ADHF [1,23–25]. While it is possible that changes in admission criteria during the pandemic also impacted hospitalization rates, various studies have documented changes in the number of patients seeking medical care, especially early during the pandemic. Outpatient visits declined by about 50% in the early period of the pandemic in the southeastern U.S. [26]. Another study that included 24 Emergency Departments in 5 health systems in 5 states found that patient visits declined between 41.5% and 63.5% in March and April of this year. Data from 5 hospitals in the UNC Health system found that the number of patients seeking Emergency Department care declined by 46.5% in March and April with the largest decline seen the week of March 11, 2020. The percentage of Emergency Department patients being admitted to the hospital were stable until COVID-19 cases increased significantly [27]. Therefore, it is likely that the decline in admissions for ADHF and AMI seen in March and April 2020 in our study was not due to changes in admission criteria but driven primarily by individuals' perception of risk in seeking care.

Several lines of evidence strongly suggest that government issued orders impact patient behaviors. First, consistent with the dramatic decrease in Emergency Department visits after the SOE [25], we found a sudden and rapid decline in acute CV hospitalizations within two weeks of the SOE declaration which is unlikely to be attributable to decreased incidence. Second, despite variance in the trends of COVID-19 cases between urban and rural areas in NC during the period of this study [16,28], both urban and rural area hospitals saw similar abrupt changes in the rates of AMI/ADHF hospitalizations following the government issued orders. The observed decrease in hospitalizations irrespective of the geographic distribution of COVID-19 suggests that the government-issued orders had a larger effect on patients' decisions to seek emergency CV care than did the actual risk of acquiring COVID-19. Lastly, our data showed that acute CV hospitalizations rebounded following the Phase 1 of Reopening order (though not to pre-COVID levels) despite an increase in COVID-19 cases, which demonstrates that government-issued orders can both enhance and reduce fear associated with seeking medical care for acute conditions. These data emphasize the immediate impact of public health messaging on human behavior, including seeking care for potentially life-threatening cardiac conditions.

While the government orders were not designed to limit patients from seeking health services for acute CV conditions, they can be misinterpreted and perceived to be applicable to even emergency medical care. Government orders may also result in significant barriers to access to primary care physicians with one study estimating that outpatient medical visits declined approximately 50% in the southeastern part of

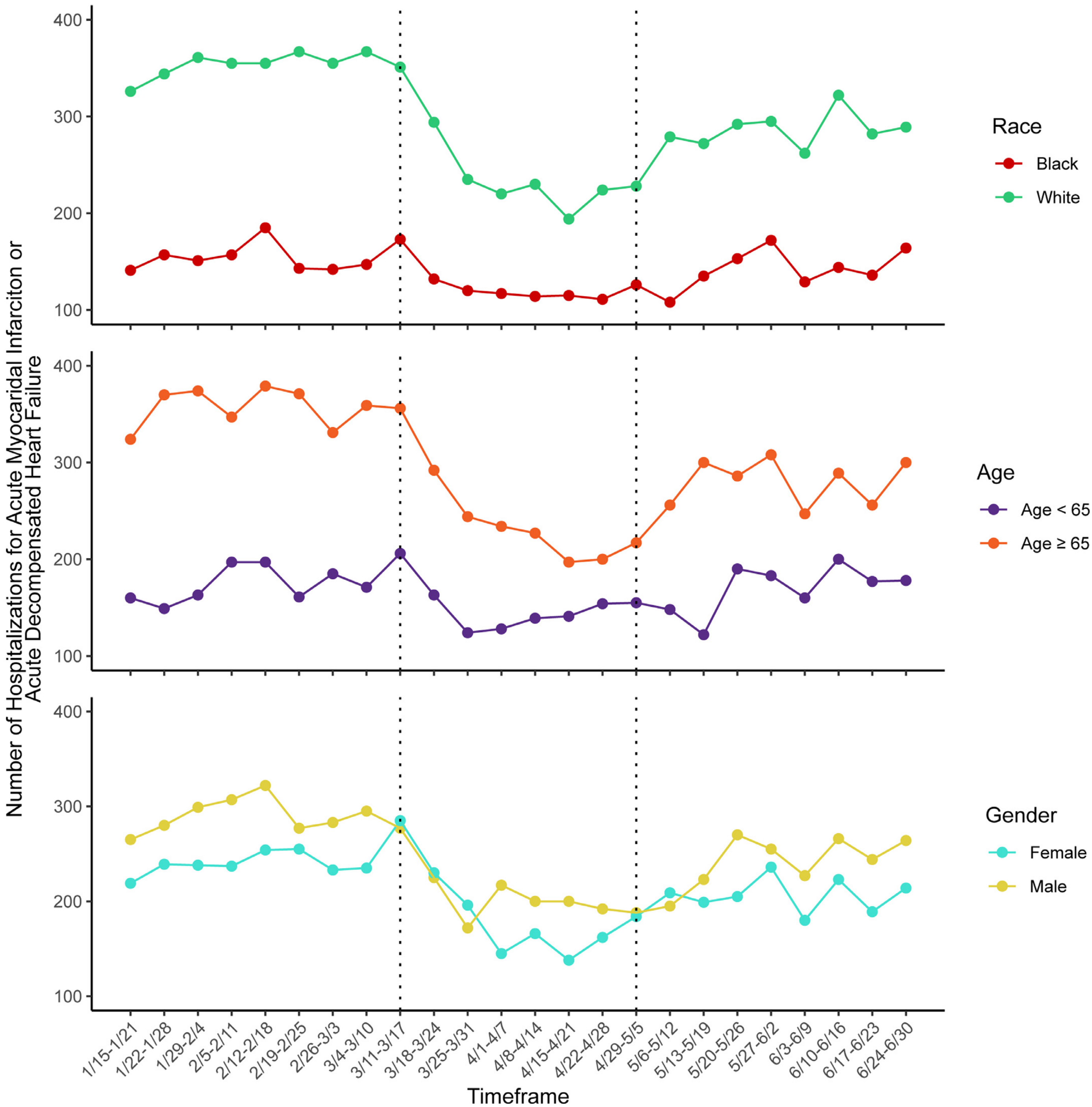


Fig. 3. Trends in acute myocardial infarction (AMI) or acute decompensated heart failure (ADHF) hospitalizations in the UNC Health System stratified by demographics, from January to June 2020.

the U.S. in March and April [26]. Furthermore, our data demonstrated larger declines in older adults, which is concerning as the government actions may have a disproportionate impact on groups who have increased perceived risk of contracting SARS-COV2. While the current study was not designed to determine the reasons behind patient decisions, it highlights the important implications of public health policy, which can significantly alter individuals' behavior and response in a pandemic.

There has been discrepancy in the literature regarding inpatient mortality in HF and AMI throughout the pandemic. Most notably, while a recent study from the Danish National dataset found no changes in overall HF mortality during the initial pandemic period [22], a study from the Providence St Joseph Health System suggested increased risk-adjusted mortality in AMI in March/April 2020[29] It would stand to reason that mortality rates of AMI change more than ADHF, as the majority of patients with ADHF carry a diagnosis of chronic HF; therefore, HF patients are more likely medically optimized, and patient education regarding alarm symptoms that warrant seeking care is likely far superior in the population with HF as compared to those with AMI, which frequently is an acute and initial cardiovascular presentation. However, our study found significant declines in hospitalizations for both AMI and ADHF, while in-hospital mortality in AMI/ADHF hospitalizations remained stable and the rates of cardiac arrest did not meaningfully change. These data must be interpreted with caution as mortality and cardiac arrest data were only available for in-hospital events. This is important as reports from Italy and New York point to a surge in rates of out-of-hospital cardiac arrest during the COVID-19 pandemic as individuals attempt to avoid hospitals [30,31]. In summary, true changes in mortality from acute CV conditions such as AMI/ADHF in the initial months of the COVID-19 pandemic remain unclear. The concern for increased rates of at-home deaths remains high and must be investigated in future analyses, especially as our data demonstrated larger declines in hospitalizations for older adults who are most at risk.

Our study has important limitations. First, we did not account for changes in the population at risk during the study period; however, it is unlikely that there were significant changes over a short time span. Second, ICD-10-CM coding practices may vary across practitioners and hospitals, and it is possible patients with AMI/ADHF were coded as having an alternate diagnosis especially if there was another primary problem. This was partially mitigated by being selective in inclusion criteria and excluding all non-acute ICD-10-CM codes (Supplemental Table 1). Third, while we were able to detect significant differences overall, some of the subgroups had relatively small sample sizes and analyses were underpowered to detect differences in these populations. Fourth, we used the county designation to classify hospitals as urban/suburban and rural; however, this likely does not fully capture or describe the patient population each hospital treats within its catchment area. Lastly, due to the functionality of i2b2, unique patients were identified within a week query, so readmissions in the same calendar week may be missed and thus hospitalizations are likely underestimated; however, we would not expect this to differ week to week.

5. Conclusions

In this study spanning 10 hospitals throughout NC, we observed sudden substantial declines in the weekly rates of AMI or ADHF hospitalizations within the two weeks following the SOE declaration in NC. There were similar declines in both urban and rural hospitals, despite a preponderance of COVID-19 for urban areas, and older individuals experienced the most substantial declines. In the setting of demonstrated declines in outpatient and emergency room visits over this period, these data raise concerns for patients avoiding care due to perceived risk of COVID-19 rather than a decrease in incidence of AMI or ADHF. After reopening measures were implemented, there was an abrupt rebound in AMI or ADHF hospitalizations despite a continued increase in COVID-19 cases. These data highlight the impact of government issued orders on individuals seeking care for essential services. Future measures may benefit from clarity regarding when patients should present for care.

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6. Author contributions

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ajpc.2021.100172.

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