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ORIGINAL RESEARCH

Impact of the COVID-19 Pandemic on Patients Without COVID-19 With Acute Myocardial Infarction and Heart Failure

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BACKGROUND: Excess mortality from cardiovascular disease during the COVID-19 pandemic has been reported. The mechanism is unclear but may include delay or deferral of care, or differential treatment during hospitalization because of strains on hospital capacity.

METHODS AND RESULTS: We used emergency department and inpatient data from a 12-hospital health system to examine changes in volume, patient age and comorbidities, treatment (right- and left-heart catheterization), and outcomes for patients with acute myocardial infarction (AMI) and heart failure (HF) during the COVID-19 pandemic compared with pre-COVID-19 (2018 and 2019), controlling for seasonal variation. We analyzed 27 427 emergency department visits or hospitalizations. Patient volume decreased during COVID-19 for both HF and AMI, but age, race, sex, and medical comorbidities were similar before and during COVID-19 for both groups. Acuity increased for AMI as measured by the proportion of patients with ST-segment elevation. There were no differences in right-heart catheterization for patients with HF or in left heart catheterization for patients with AMI. In-hospital mortality increased for AMI during COVID-19 (odds ratio [OR], 1.46; 95% CI, 1.21–1.76), particularly among the ST-segment–elevation myocardial infarction subgroup (OR, 2.57; 95% CI, 2.24–2.96), but was unchanged for HF (OR, 1.02; 95% CI, 0.89–1.16).

CONCLUSIONS: Cardiovascular volume decreased during COVID-19. Despite similar patient age and comorbidities and in-hospital treatments during COVID-19, mortality increased for patients with AMI but not patients with HF. Given that AMI is a time-sensitive condition, delay or deferral of care rather than changes in hospital care delivery may have led to worse cardiovascular outcomes during COVID-19.

Key Words: acute myocardial infarction ■ COVID-19 ■ heart failure ■ spillover

The COVID-19 pandemic has led to 46 million infections and >700 000 deaths in the United States alone. However, its impact also affected non-COVID-19 medical conditions. Prior studies suggest that there was significant excess mortality from causes other than COVID-19 during the pandemic, including from cardiovascular disease.[1-5]

However, the cause for increased cardiovascular mortality during the COVID-19 pandemic remains unclear. One hypothesis is that the higher mortality is attributable to delay or deferral of care.[5,6] Perhaps in part because of fear of exposure to COVID-19, patients may have presented later to hospital systems, and as such were sicker and had more adverse outcomes while hospitalized.[6,7] For example, one recent study showed that heart failure (HF) hospitalizations decreased by ≈41% in an Australian cohort.[8] Hospitalizations for acute coronary syndromes appear to have decreased during the COVID-19 pandemic in multiple areas as well.[9-11]

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CLINICAL PERSPECTIVE

What Is New?

- During the first year of the COVID-19 pandemic, admissions and emergency department visit volume decreased for acute myocardial infarction and heart failure compared with prior years, but there were no observed changes in patient age, comorbidities, or treatments offered.
- However, among patients with acute myocardial infarction, there was significantly higher acuity (proportion of ST-segment–elevation myocardial infarction, proportion of admissions originating in the emergency department) during COVID-19 and higher mortality.

What Are the Clinical Implications?

- Given that we did not see differences in age, comorbidities, or treatment, but did see higher acuity for AMI, we hypothesize that delay or deferral of care as opposed to disruption of hospital care may have led to the observed differences in acute myocardial infarction mortality during COVID-19.
- Educating patients on the importance of seeking necessary medical care and providing safe means of accessing care may serve as an important intervention to reduce negative spillover effects of the COVID-19 pandemic on cardiovascular care and outcomes.

Nonstandard Abbreviations and Acronyms

LHC	left-heart catheterization
RHC	right-heart catheterization

Another possibility is that patients who did present to the hospital were treated differently because of hospital limitations at the time, whether related to bed shortages, staff shortages, or changes in protocol.[12,13] For example, one German study showed that the rate of percutaneous coronary intervention decreased for patients with acute coronary syndromes during COVID-19,[14] and a recent Swiss and Spanish study showed similar findings.[15] Another study showed that patients with HF hospitalized during the COVID-19 pandemic were less likely to receive guideline-directed medical therapy for left ventricular dysfunction on hospital discharge compared with prior years.[8]

Understanding whether delays in presentation or differences in treatment were associated with worse outcomes is important as clinical leaders and policymakers seek to deal with ongoing and future surges of COVID-19 or other challenges to the health care system in a way that protects patients. We therefore set out to answer 4 research questions using emergency department (ED) and inpatient hospitalization data from a 12-hospital health care system in the Midwest, examining both patients with acute myocardial infarction (AMI) and patients with HF:

1. Were there changes in volume of ED visits and hospitalizations for AMI or HF during COVID-19 compared with similar calendar months in the 2 years prior?
2. Among patients who did present with AMI or HF, was there evidence of a higher number of comorbidities or advanced age?
3. Among admitted patients with AMI or HF, were treatments such as cardiac catheterization used differently during COVID-19?
4. Were there differences in outcomes for AMI or HF during COVID-19?

METHODS

Data

In this observational study, we used claims data to examine all ED and inpatient hospitalization visits without a documented COVID-19 diagnosis to 12 hospitals in the BJC Healthcare organization, a large health system in the St. Louis metropolitan region, between January 1, 2018, and September 23, 2020. These data include check-in and discharge or death date, as well as patient age; sex; race; insurance payor (primary); and *International Classification of Diseases, Tenth Revision* (*ICD-10*) diagnosis and procedure codes. As 97% of our patient population was composed of Black and White patients, other races were not included in our final analyses because of small sample size.

This study was approved by the Washington University Office of Human Subjects Protection. Requirement for informed consent was waived because of the observational nature of the study and the deidentified nature of the data. Because the data contain identifiable information on individual patients, they cannot be made publicly available and cannot be shared without specific institutional approval. However, researchers wishing to access deidentified parts of the data set should contact the corresponding author.

Analytic Data Set Description

Our sample included 27 427 ED and inpatient visits over the time period from January 1, 2018, through September 22, 2020, in the BJC Healthcare system, which includes 12 of 13 hospitals (we excluded St. Louis

Children's Hospital to focus on our target population, age >18 years). We divided the data set into seasons to account for any seasonal variation noted previously for HF hospitalizations[16,17] and AMI hospitalizations,[18,19] categorizing winter (December 21–March 20), spring (March 21 to June 20), summer (June 21–September 20), and fall (September 21–December 20) in each year. Of note, the St. Louis City and County "Stay at Home" ordinances were put in place on March 23, 2020, and discontinued on May 19, 2020. COVID-19 events were defined as ED visits and hospitalizations occurring between March 21, 2020, and September 22, 2020.

Predictors

Our primary predictor was whether or not the clinical event took place during COVID-19. We used an indicator variable to describe ED and inpatient hospitalizations before and following the St. Louis City and St. Louis County Stay at Home orders from March 21, 2020. Clinical comorbidities were defined using the Elixhauser approach, which is a validated method to risk-adjust in-hospital outcomes.

Outcomes

Outcome measures included volume (the daily number of non-COVID-19 ED and inpatient hospitalizations), patient age and medical comorbidities, in-hospital treatments, and mortality. For in-hospital treatments, we examined the use of left-heart catheterization (LHC) for patients with AMI, and right-heart-catheterization (RHC) for patients with HF. We counted hospitalizations as having an LHC if the claim contained an *ICD-10* procedure code for LHC or percutaneous coronary intervention. WhileRHC is not a routine part of HF care, it can be of utility for particularly ill or otherwise challenging patients. An increase in use might indicate that patients were sicker during COVID-19; a decrease might indicate more hesitancy to perform procedures.

Statistical Analysis

Patient characteristics were summarized by season and COVID-19 time period, and compared using chi-squared tests and *t*-tests as appropriate. Graphical representations of trends in mortality rates were created using locally estimated scatterplot smoothing regression, fitting a locally weighted model surrounding every week that describes the proportion of hospitalizations that ended in death and how it varies over time. Raw rates of characteristics of presentation and in-hospital treatments and outcomes were similarly summarized by season and COVID-19 time period and compared using chi-squared tests and *t*-tests. As a falsification test, we evaluated whether any of these key elements differed between 2018 and 2019. To determine whether COVID-19 was associated with receipt of specific treatments (RHC/LHC) or with higher mortality in either cohort, logistic regression models fit using generalized estimating equations were used to control for key medical comorbidities, age, race, insurance, and seasonal variation, as well as to account for within-site clustering.

P values <0.05 were considered statistically significant. All statistical analyses were performed using R version 4.0.2. This study was approved by the Office of Human Research Protection at the Washington University School of Medicine. The requirement for informed consent and Health Insurance Portability and Accountability Act notification were waived because of the deidentified nature of the data.

RESULTS

Changes in Volume and Patient Demographics and Comorbidities

For the HF cohort, there were 21 262 total visits during the study period (Table 1). Daily patient volume decreased in COVID-19 compared with pre-COVID-19 (20.7–22.3 events/day pre-COVID-19, 17.0–18.3 events/day during COVID-19; *P*<0.001). While sex distribution was unchanged, patients during COVID-19 were more often Black, more often insured by Medicaid or self-pay, and tended to have a higher prevalence of liver disease and fluid and electrolyte disorders, though differences were small and of uncertain clinical significance.

For the AMI cohort, there were 6165 total visits in our study period. Similar to the HF cohort, patient volume decreased in COVID-19 compared with pre-COVID-19 (6.1–6.6 events/day pre-COVID-19, 4.9–5.5 events/day during COVID-19; *P*<0.001; Table 1). However, there were no meaningful differences in sex, race, insurance status, or medical comorbidities.

Falsification testing comparing 2018 with 2019 yielded similar demographics, but small differences in the prevalence of comorbidities in the HF cohort, and no meaningful differences in the AMI cohort (Table S1).

Changes in Hospitalization Characteristics and In-Hospital Treatments

Among the HF cohort, there was no difference in the proportion of patients presenting with cardiogenic shock, but the proportion of admissions originating in the ED increased slightly during COVID-19 (83.8%–84.9% pre-COVID-19, 85.7%–86.8% during COVID-19; *P*=0.04; Table 2). There was no difference in the rate of RHC (8.3%–8.4% pre-COVID-19, 8.9%–10.7% during COVID-19; *P*=0.43), length of stay (4.78–4.83 days pre-COVID-19, 4.76–4.9 days during COVID-19) or mortality (1.8%–2.2% pre-COVID-19, 1.6%–2.7% during COVID-19; *P*=0.94). There was a decrease in

Table 1. Patient Characteristics

Heart failure cohort	Pre-COVID-19 (January 1, 2018–March 20, 2020)				COVID-19 (March 21, 2020–September 21, 2020)		*P* value
	Winter	Spring	Summer	Fall	Spring	Summer	
	(N=5948)	(N=4163)	(N=3844)	(N=4016)	(N=1565)	(N=1685)	
Daily volume	23.6 (6.30)	22.3 (6.02)	20.7 (5.71)	22.3 (5.84)	17.0 (5.75)	18.3 (4.94)	<0.001
Sex							
Female	2907 (48.9)	2007 (48.2)	1981 (51.5)	1958 (48.8)	759 (48.5)	793 (47.1)	0.05
Male	3041 (51.1)	2156 (51.8)	1863 (48.5)	2058 (51.2)	806 (51.5)	892 (52.9)	
Race							
Black	2397 (40.3)	1731 (41.6)	1613 (42.0)	1699 (42.3)	690 (44.1)	746 (44.3)	0.02
White	3551 (59.7)	2432 (58.4)	2231 (58.0)	2317 (57.7)	875 (55.9)	939 (55.7)	
Insurance							
Commercial	653 (11.0)	457 (11.0)	412 (10.7)	433 (10.8)	158 (10.1)	184 (10.9)	<0.001
Medicaid	737 (12.4)	524 (12.6)	478 (12.4)	497 (12.4)	249 (15.9)	263 (15.6)	
Medicare	4394 (73.9)	3084 (74.1)	2858 (74.3)	2978 (74.2)	1107 (70.7)	1178 (69.9)	
Self pay	164 (2.8)	98 (2.4)	96 (2.5)	108 (2.7)	51 (3.3)	60 (3.6)	
Comorbidities							
Renal failure	3423 (57.5)	2348 (56.4)	2189 (56.9)	2377 (59.2)	870 (55.6)	982 (58.3)	0.77
Liver disease	326 (5.5)	258 (6.2)	215 (5.6)	259 (6.4)	127 (8.1)	111 (6.6)	0.01
Diabetes	2419 (40.7)	1655 (39.8)	1491 (38.8)	1617 (40.3)	610 (39.0)	671 (39.8)	0.92
Valvular heart disease	1656 (27.8)	1088 (26.1)	1009 (26.2)	1072 (26.7)	399 (25.5)	425 (25.2)	0.37
Hypertension	5424 (91.2)	3786 (90.9)	3550 (92.4)	3716 (92.5)	1438 (91.9)	1552 (92.1)	0.53
Chronic pulm. disease	2526 (42.5)	1844 (44.3)	1712 (44.5)	1730 (43.1)	682 (43.6)	720 (42.7)	0.23
Fluid/electrolyte disorder	1994 (33.5)	1347 (32.4)	1273 (33.1)	1342 (33.4)	628 (40.1)	654 (38.8)	<0.001
Obesity	1573 (26.4)	1151 (27.6)	986 (25.7)	1046 (26.0)	416 (26.6)	492 (29.2)	0.18
AMI cohort	**Pre-COVID-19 (January 1, 2018–March 20, 2020)**				**COVID-19 (March 21, 2020–September 21, 2020)**		***P* value**
	Winter	**Spring**	**Summer**	**Fall**	**Spring**	**Summer**	
	(N=1645)	**(N=1234)**	**(N=1128)**	**(N=1186)**	**(N=450)**	**(N=505)**	
Daily volume	6.55 (2.70)	6.63 (2.54)	6.1 (2.26)	6.59 (2.72)	4.89 (2.28)	5.49 (2.31)	<0.001
Sex							
Female	630 (38.3)	468 (37.9)	458 (40.6)	459 (38.7)	163 (36.2)	196 (38.8)	0.41
Male	1015 (61.7)	766 (62.1)	670 (59.4)	727 (61.3)	287 (63.8)	309 (61.2)	
Race							
Black	369 (22.4)	258 (20.9)	239 (21.2)	250 (21.1)	97 (21.6)	116 (23.0)	0.45
White	1276 (77.6)	976 (79.1)	889 (78.8)	936 (78.9)	353 (78.4)	389 (77.0)	
Insurance							
Commercial	454 (27.6)	310 (25.1)	296 (26.2)	320 (27.0)	114 (25.3)	131 (25.9)	0.94
Medicaid	142 (8.6)	94 (7.6)	94 (8.3)	75 (6.3)	40 (8.9)	42 (8.3)	
Medicare	977 (59.4)	757 (61.3)	671 (59.5)	729 (61.5)	273 (60.7)	297 (58.8)	
Self-pay	72 (4.4)	73 (5.9)	67 (5.9)	62 (5.2)	23 (5.1)	35 (6.9)	
Comorbidities							
Renal failure	476 (28.9)	328 (26.6)	337 (29.9)	358 (30.2)	140 (31.1)	159 (31.5)	0.08
Liver disease	85 (5.2)	58 (4.7)	51 (4.5)	48 (4.0)	29 (6.4)	25 (5.0)	0.24
Diabetes	487 (29.6)	354 (28.7)	332 (29.4)	358 (30.2)	123 (27.3)	145 (28.7)	0.60
Valvular heart disease	330 (20.1)	204 (16.5)	203 (18.0)	220 (18.5)	83 (18.4)	86 (17.0)	0.79
Hypertension	805 (48.9)	572 (46.4)	542 (48.0)	586 (49.4)	216 (48.0)	251 (49.7)	0.39

(*Continued*)

Table 1. Continued

AMI cohort	Pre-COVID-19 (January 1, 2018–March 20, 2020)				COVID-19 (March 21, 2020–September 21, 2020)		*P* value
	Winter (N=1645)	Spring (N=1234)	Summer (N=1128)	Fall (N=1186)	Spring (N=450)	Summer (N=505)	
Chronic pulmonary disease	420 (25.5)	325 (26.3)	301 (26.7)	268 (22.6)	113 (25.1)	124 (24.6)	0.34
Fluid/electrolyte disorder	468 (28.4)	313 (25.4)	310 (27.5)	347 (29.3)	137 (30.4)	133 (26.3)	0.28
Obesity	360 (21.9)	261 (21.2)	228 (20.2)	251 (21.2)	92 (20.4)	99 (19.6)	0.68

Variables were reported as numbers and percentages. *P* value compares spring/summer pre-COVID-19 to spring/summer during COVID-19.
AMI indicates acute myocardial infarction.

discharge to postacute care and an increase in discharges home with services.

For the AMI cohort, the proportion of admissions originating in the ED increased during COVID-19 (74.5%–76.9% pre-COVID-19, 80.4%–82.8% during COVID-19; *P*=0.001; Table 2). A higher proportion of patients with AMI were admitted with ST-segment–elevation myocardial infarction (STEMI; 29.0%–29.3% pre-COVID-19 to 32.5%–37.6% during COVID-19; *P*=0.005). Rates of LHC and length of stay were similar pre-COVID-19 versus during COVID-19, but mortality was higher during COVID-19 (1.8%–2.2% pre-COVID-19, 1.6%–2.7% during COVID-19; *P*<0.001). Discharge status was more often home with services and less often postacute care during COVID-19.

Falsification testing comparing 2018 with 2019 yielded no significant differences between the 2 years for either cohort (Table S2).

Odds of Mortality in HF and AMI Cohorts

Raw mortality rates for the AMI and HF cohorts are shown in the Figure 1. After controlling for age, comorbidities, and season, for the AMI group, odds of in-hospital mortality was increased during COVID-19 (adjusted odds ratio [aOR], 1.36; 95% CI, 1.15–1.60; *P*=0.001) compared with the pre-COVID-19 time period (Table 3). This was particularly striking in the STEMI subgroup (aOR, 2.57; 95% CI, 2.24–2.96; *P*<0.001).

Again controlling for age, comorbidities, and season, for the HF group, we saw no difference in the odds of mortality during the COVID-19 versus pre-COVID-19 time period (aOR, 1.01; 95% CI, 0.89–1.15; *P*=0.91; Table 3).

DISCUSSION

In a large Midwestern hospital system, we found that for both HF and AMI, patient volume decreased markedly during COVID-19. While patients' mean age and prevalence of comorbidities were largely unchanged, there was evidence of higher acuity at presentation as reflected in a higher proportion of patients with STEMI in the AMI cohort. The use of key treatments such as LHC was unchanged. Mortality was significantly higher within the AMI cohort during COVID-19, though it was stable within the HF cohort.

Our data show a decrease in patient volume during the COVID-19 time period when compared with prior seasons. These data are consistent with multiple studies showing a decrease in both HF and acute coronary syndrome hospitalizations during COVID-19.[9-11, 20-23] The mechanism for this decrease is likely multifactorial, the first of which is a delay or deferral in care because of ED and hospital aversion. This has been described in a number of circumstances both in the United States and abroad. Some patients were likely reacting to local or state-level orders put in place (eg, Stay at Home ordinances), perhaps unaware that such orders did not apply to people who needed medical care. However, others may have been primarily motivated by fear of contracting COVID-19, particularly given the images in the popular press of overcrowded EDs and overwhelmed clinicians in areas hard hit by early waves of the pandemic.

We did not find any difference in key treatment modalities (LHC for the AMI group and RHC for the HF group) during versus before COVID-19. In contrast, other studies have shown reductions in treatments among these patient populations. Specifically, 2 recent studies have shown a decrease in LHC for acute coronary syndrome hospitalizations as a potential mechanism.[10,14] In another study, patients were less likely to receive HF guideline-directed medical therapy on hospital discharge.[8] The difference in our findings and other recent studies may be explained by regional differences in the severity of the pandemic; in greater St. Louis, COVID-19 volumes never overwhelmed local hospital systems. Our sample may have been able to continue "business as usual" for critically ill patients, even though elective procedures and outpatient care were disrupted.

Despite the lack of measured differences in comorbidities or treatments, our data show increased

Table 2. Changes in Presentation, In-Hospital Treatments, and Outcomes

	Pre-COVID-19 (January 1, 2018–March 20, 2020)				COVID-19 (March 21, 2020–September 21, 2020)		
	Winter	Spring	Summer	Fall	Spring	Summer	*P* value
Heart failure cohort							
Presentation severity							
Cardiogenic shock	215 (3.6)	165 (4.0)	135 (3.5)	174 (4.3)	61 (3.9)	62 (3.7)	215 (3.6)
ED admission	4998 (84.0)	3490 (83.8)	3265 (84.9)	3380 (84.2)	1341 (85.7)	1462 (86.8)	0.041
Direct admission	933 (15.7)	659 (15.8)	566 (14.7)	627 (15.6)	221 (14.1)	218 (12.9)	0.053
In-hospital procedures/outcomes							
Right-heart catheterization	474 (8.0)	349 (8.4)	319 (8.3)	339 (8.4)	139 (8.9)	180 (10.7)	0.431
LOS, mean (SD)	4.85 (6.16)	4.78 (6.26)	4.83 (6.31)	4.96 (7.28)	4.90 (5.96)	4.76 (5.33)	0.973
Death	145 (2.4)	93 (2.2)	69 (1.8)	94 (2.3)	42 (2.7)	27 (1.6)	0.944
Discharge status							
Against medical advice	110 (1.8)	87 (2.1)	92 (2.4)	68 (1.7)	38 (2.4)	55 (3.3)	<0.001
Home	3716 (62.5)	2594 (62.3)	2404 (62.5)	2511 (62.5)	1003 (64.1)	1070 (63.5)	
Home with services	933 (15.7)	694 (16.7)	603 (15.7)	643 (16.0)	293 (18.7)	314 (18.6)	
Other	63 (1.1)	45 (1.1)	32 (0.8)	35 (0.9)	15 (1.0)	17 (1.0)	
Postacute care	981 (16.5)	650 (15.6)	644 (16.8)	665 (16.6)	174 (11.1)	202 (12.0)	
AMI cohort							
Presentation severity							
Cardiogenic shock	184 (11.2)	140 (11.3)	117 (10.4)	120 (10.1)	60 (13.3)	58 (11.5)	184 (11.2)
ED admission	1275 (77.5)	949 (76.9)	840 (74.5)	949 (80.0)	362 (80.4)	418 (82.8)	0.001
Direct admission	368 (22.4)	280 (22.7)	286 (25.4)	237 (20.0)	88 (19.6)	87 (17.2)	0.002
NSTEMI	1147 (69.7)	873 (70.7)	801 (71.0)	861 (72.6)	281 (62.4)	341 (67.5)	0.005
STEMI	498 (30.3)	361 (29.3)	327 (29.0)	325 (27.4)	169 (37.6)	164 (32.5)	
Procedures and LOS							
Left heart catheterization	1130 (68.7)	879 (71.2)	801 (71.0)	843 (71.1)	315 (70.0)	362 (71.7)	0.991
LOS, mean (SD)	5.22 (5.92)	5.17 (6.71)	5.09 (6.21)	5.05 (6.94)	4.98 (6.73)	4.42 (5.19)	0.184
Death	145 (2.4)	93 (2.2)	69 (1.8)	94 (2.3)	42 (2.7)	27 (1.6)	<0.001
Discharge status							
Against medical advice	110 (1.8)	87 (2.1)	92 (2.4)	68 (1.7)	38 (2.4)	55 (3.3)	<0.001
Home	3716 (62.5)	2594 (62.3)	2404 (62.5)	2511 (62.5)	1003 (64.1)	1070 (63.5)	
Home with services	933 (15.7)	694 (16.7)	603 (15.7)	643 (16.0)	293 (18.7)	314 (18.6)	
Other	63 (1.1)	45 (1.1)	32 (0.8)	35 (0.9)	15 (1.0)	17 (1.0)	
Post-acute care	981 (16.5)	650 (15.6)	644 (16.8)	665 (16.6)	174 (11.1)	202 (12.0)	

Categorical variables were reported as numbers and percentages, and continuous variables were reported as means and standard deviations. *P* value compares spring/summer pre-COVID-19 to spring/summer during COVID-19.

AMI indicates acute myocardial infarction; ED, emergency department; LOS, length of stay; NSTEMI, non–ST-segment–elevation myocardial infarction; and STEMI, ST-segment–elevation myocardial infarction.

in-hospital mortality for the AMI cohort during COVID-19, a pattern that was not seen in the HF cohort. In addition to the higher prevalence of STEMI in our cohort, we suspect that patients presenting with AMI also differed compared with prior years in ways that were not easily captured in our claims data.[24] For example, patients may have waited longer to seek care in the ED when experiencing chest pain or other symptoms, and many patients with milder symptoms may have elected not to come in at all. The long-term effects of these shifts remain to be seen, as it is possible that delay or deferral of care for AMI in the near term may bring higher rates of recurrent ischemia or HF in the longer-term.

Patterns for HF may differ from those for AMI because these 2 cardiovascular conditions have very different pathophysiologies. Among patients with HF, symptoms are generally gradual in onset; it is possible that some patients who preferred to avoid the ED were instead treated presumptively over the phone, or even did their own medication titration. Patients who did present, even if they were somewhat sicker at the time

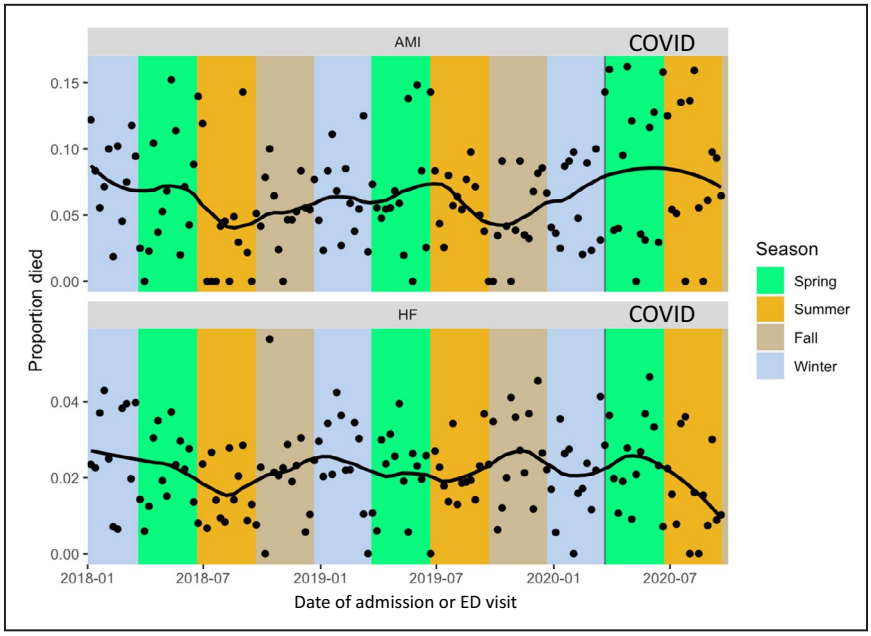

Figure. Raw weekly mortality rates during the study period.
AMI indicates acute myocardial infarction; ED, emergency department; and HF, heart failure.

of arrival, may still have been within a window in which they could respond well to typical treatments. On the other hand, AMI is generally sudden in onset, and treatment far more time sensitive; even small delays in seeking care may be associated with poor outcomes. Interestingly, while others have shown a decrease in HF hospitalizations during COVID-19, thus far none find an effect on in-hospital mortality.[8,20,21,23,25]

There are limitations to our findings. Our study is limited to the patient population studied, a 12-hospital system in a midsize US city. While likely representative of our region, these data may not generalize to other regional health systems in the United States or to international patient populations. Because we used administrative data, we are limited in our ability to determine clinical presentation severity, as well as treatment elements such as door-to-balloon time. For the HF cohort, we are limited in our detection of certain HF treatments (such as goal-directed medical therapy for left ventricular dysfunction). Low rates of HF mortality may have underpowered our mortality comparison. Additionally, these data are limited to a discrete time period (January 1, 2018, to September 22, 2020) and may not reflect patterns during later time frames; other studies have suggested that the reduction in cardiovascular volume seen with COVID-19's initial surge may not have persisted during subsequent waves.[26] Finally, we are limited in our follow-up and did not capture postdischarge events such as 30-day mortality; longer-term study is needed to determine whether there are additional consequences of near-term delays or deferrals of care.

In conclusion, cardiovascular volume (both AMI and HF) of ED visits and hospitalizations decreased significantly during COVID-19, but patient age, comorbidities, and treatment patterns were largely unchanged. Mortality was higher for myocardial infarction but stable

Table 3. Odds of Procedure Use and Mortality in HF and AMI Cohorts

	aOR, COVID-19 vs non-COVID-19	Lower CI	Upper CI	*P* value
AMI				
Mortality (all)	1.36	1.15	1.60	<0.001
Mortality (STEMI)	2.57	2.24	2.96	<0.001
Left-heart catheterization (all)	1.02	0.88	1.19	0.77
Heart failure				
Mortality	1.01	0.89	1.15	0.91
Right-heart catheterization	1.07	0.92	1.25	0.36

Models control for age, race, insurance status, Elixhauser comorbidities, and season. The non-COVID-19 time periods serve as the reference group, such that odds ratios >1 indicate a higher odds of the event during COVID-19.
AMI indicates acute myocardial infarction; aOR, adjusted odds ratio; and STEMI, ST-segment–elevation myocardial infarction.

for HF during the pandemic. Collectively, these data raise the possibility that deferral in care is the most likely mechanism for increased cardiovascular mortality during COVID-19, and that public health efforts aimed at educating patients on the importance of seeking necessary medical care might be an important intervention to reduce excess mortality associated with COVID-19.

ARTICLE INFORMATION

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Supplemental Material

Supplemental Material
Tables S1–S2

REFERENCES

1. Aladağ N, Atabey RD. The role of concomitant cardiovascular diseases and cardiac biomarkers for predicting mortality in critical COVID-19 patients. *Acta Cardiol*. 2021;76:132–139. doi: 10.1080/00015385.2020.1810914
2. Li X, Guan B, Su T, Liu W, Chen M, Bin Waleed K, Guan X, Gary T, Zhu Z. Impact of cardiovascular disease and cardiac injury on in-hospital mortality in patients with COVID-19: a systematic review and meta-analysis. *Heart*. 2020;106:1142–1147. doi: 10.1136/heartjnl-2020-317062
3. McGonagle D, Plein S, O'Donnell JS, Sharif K, Bridgewood C. Increased cardiovascular mortality in African Americans with COVID-19. *Lancet Respir Med*. 2020;8:649–651. doi: 10.1016/S2213-2600(20)30244-7
4. Mehra MR, Desai SS, Kuy S, Henry TD, Patel AN. Cardiovascular disease, drug therapy, and mortality in COVID-19. *New Engl J Med*. 2020;382:e102.
5. Wu J, Mamas MA, Mohamed MO, Kwok CS, Roebuck C, Humberstone B, Denwood T, Luescher T, de Belder MA, Deanfield JE, et al. Place and causes of acute cardiovascular mortality during the COVID-19 pandemic. *Heart*. 2021;107:113–119. doi: 10.1136/heartjnl-2020-317912
6. Boserup B, McKenney M, Elkbuli A. The impact of the COVID-19 pandemic on emergency department visits and patient safety in the United States. *Am J Emerg Med*. 2020;38:1732–1736. doi: 10.1016/j.ajem.2020.06.007
7. Westgard BC, Morgan MW, Vazquez-Benitez G, Erickson LO, Zwank MD. An analysis of changes in emergency department visits after a state declaration during the time of COVID-19. *Ann Emerg Med*. 2020;76:595–601. doi: 10.1016/j.annemergmed.2020.06.019
8. Toner L, Koshy AN, Ko J, Driscoll A, Farouque O. Clinical characteristics and trends in heart failure hospitalizations: an Australian experience during the COVID-19 lockdown. *JACC Heart Fail*. 2020;8:872–875.
9. Huynh K. Reduced hospital admissions for ACS – more collateral damage from COVID-19. *Nat Rev Cardiol*. 2020;17:453. doi: 10.1038/s41569-020-0409-5
10. Gitt AK, Karcher AK, Zahn R, Zeymer U. Collateral damage of covid-19-lockdown in Germany: decline of NSTE-ACS admissions. *Clin Res Cardiol*. 2020;109:1585–1587.
11. De Filippo O, D'Ascenzo F, Angelini F, Bocchino PP, Conrotto F, Saglietto A, Secco GG, Campo G, Gallone G, Verardi R, et al. Reduced rate of hospital admissions for ACS during COVID-19 outbreak in northern Italy. *New Engl J Med*. 2020;383:88–89. doi: 10.1056/NEJMc2009166
12. Carenzo L, Costantini E, Greco M, Barra FL, Rendiniello V, Mainetti M, Bui R, Zanella A, Grasselli G, Lagioia M, et al. Hospital surge capacity in a tertiary emergency referral centre during the COVID-19 outbreak in Italy. *Anaesthesia*. 2020;75:928–934.
13. Zhou W, Wang A, Wang X, Cheke RA, Xiao Y, Tang S. Impact of hospital bed shortages on the containment of COVID-19 in Wuhan. *Int J Environ Res Public Health*. 2020;17:8560.
14. Nef HM, Elsässer A, Möllmann H, Abdel-Hadi M, Bauer T, Brück M, Eggebrecht H, Ehrlich JR, Ferrari MW, Fichtlscherer S, et al. Impact of the COVID-19 pandemic on cardiovascular mortality and catherization activity during the lockdown in central Germany: an observational study. *Clin Res Cardiol*. 2021;110:292–301. doi: 10.1007/s00392-020-01780-0
15. Roffi M, Guagliumi G, Ibanez B. The obstacle course of reperfusion for ST-segment-elevation myocardial infarction in the COVID-19 pandemic. *Circulation*. 2020;141:1951–1953. doi: 10.1161/CIRCULATIONAHA.120.047523
16. Patel NJ, Nalluri N, Deshmukh A, Pant S, Shah N, Badheka AO, Asti D, Lafferty JC, Schwartz C. Seasonal trends of heart failure hospitalizations in the United States: a national perspective from 2000 to 2011. *Int J Cardiol*. 2014;173:562–563. doi: 10.1016/j.ijcard.2014.03.122
17. Gallerani M, Boari B, Manfredini F, Manfredini R. Seasonal variation in heart failure hospitalization. *Clin Cardiol*. 2011;34:389–394. doi: 10.1002/clc.20895
18. Chongprasertpon N, Coughlan JJ, Cahill C, Kiernan TJ. Circadian and seasonal variations in patients with acute STEMI: a retrospective, single PPCI center study. *Chronobiol Int*. 2018;35:1663–1669. doi: 10.1080/07420528.2018.1500478
19. Hodzic E, Perla S, Iglica A, Vucijak M. Seasonal incidence of acute coronary syndrome and its features. *Mater Sociomed*. 2018;30:10–14. doi: 10.5455/msm.2018.30.10-14
20. Gonzalez Manzanares R, Pericet Rodriguez C, Gallo Fernandez I, Castillo Dominguez JC, Anguita SM. Heart failure hospitalization during COVID-19 pandemic. *Semergen*. 2020;46(Suppl 1):91–92.
21. Bromage DI, Cannata A, Rind IA, Gregorio C, Piper S, Shah AM, McDonagh TA. The impact of COVID-19 on heart failure hospitalization and management: report from a heart failure unit in London during the peak of the pandemic. *Eur J Heart Fail*. 2020;22:978–984.
22. Alvarez-Garcia J, Lee S, Gupta A, Cagliostro M, Joshi AA, Rivas-Lasarte M, Contreras J, Mitter SS, LaRocca G, Tlachi P, et al. Prognostic impact of prior heart failure in patients hospitalized with COVID-19. *J Am Coll Cardiol*. 2020;76:2334–2348.
23. Hall ME, Vaduganathan M, Khan MS, Papadimitriou L, Long RC, Hernandez GA, Moore CK, Lennep BW, McMullan MR, Butler J. Reductions in heart failure hospitalizations during the COVID-19 pandemic. *J Card Fail*. 2020;26:462–463. doi: 10.1016/j.cardfail.2020.05.005
24. Garcia S, Dehghani P, Grines C, Davidson L, Nayak KR, Saw J, Waksman R, Blair J, Akshay B, Garberich R, et al. Initial findings from the North American COVID-19 myocardial infarction registry. *J Am Coll Cardiol*. 2021;77:1994–2003. doi: 10.1016/j.jacc.2021.02.055
25. Bhatt AS, Jering KS, Vaduganathan M, Claggett BL, Cunningham JW, Rosenthal N, Signorovitch J, Thune JJ, Vardeny O, Solomon SD. Clinical outcomes in patients with heart failure hospitalized with COVID-19. *JACC Heart Fail*. 2021;9:65–73.
26. Solomon MD, Nguyen-Huynh M, Leong TK, Alexander J, Rana JS, Klingman J, Go AS. Changes in patterns of hospital visits for acute myocardial infarction or ischemic stroke during COVID-19 surges. *JAMA*. 2021;326:82.

SUPPLEMENTAL MATERIAL

Table S1. Falsification testing for 2018 versus 2019, Patient Characteristics.

Heart Failure Cohort	2018	2019	P value
Daily Volume (n)	20.9	23.4	<0.001
Insurance			
Commercial	805 (10.7%)	948 (11.1%)	0.601
Medicaid	904 (12.0%)	1065 (12.5%)	
Medicare	5619 (74.8%)	6298 (73.8%)	
Self Pay	188 (2.5%)	221 (2.6%)	
Sex			
Female	3767 (50.1%)	4147 (48.6%)	0.0576
Male	3749 (49.9%)	4385 (51.4%)	
Race			
Black	3063 (40.8%)	3579 (41.9%)	0.129
White	4453 (59.2%)	4953 (58.1%)	
Comorbidities			
Renal Failure	4157 (55.3%)	5032 (59.0%)	<0.001
Liver Disease	418 (5.6%)	518 (6.1%)	0.18
Diabetes (complicated)	2925 (38.9%)	3451 (40.4%)	0.0498
Valvular Heart Disease	2141 (28.5%)	2189 (25.7%)	<0.001
Hypertension (complicated)	6774 (90.1%)	7910 (92.7%)	<0.001
Chronic Pulmonary Disease	3186 (42.4%)	3769 (44.2%)	0.0237
Fluid/Electrolyte Disorder	2380 (31.7%)	2911 (34.1%)	0.00103
Obesity	1998 (26.6%)	2246 (26.3%)	0.724

P value compares 2018 to 2019.

Table S1. Falsification testing for 2018 versus 2019, Patient Characteristics (continued)

AMI Cohort	2018	2019	P value
Daily Volume (n)	6.58	6.46	0.5402
Insurance			
Commercial	624 (26.5%)	634 (27.0%)	0.936
Medicaid	177 (7.5%)	184 (7.8%)	
Medicare	1422 (60.4%)	1408 (59.9%)	
Self Pay	132 (5.6%)	126 (5.4%)	
Sex			
Female	928 (39.4%)	901 (38.3%)	0.458
Male	1427 (60.6%)	1451 (61.7%)	
Race			
Black	512 (21.7%)	486 (20.7%)	0.385
White	1843 (78.3%)	1866 (79.3%)	
Comorbidities			
Renal Failure	654 (27.8%)	698 (29.7%)	0.158
Liver Disease	106 (4.5%)	111 (4.7%)	0.774
Diabetes (complicated)	677 (28.7%)	707 (30.1%)	0.339
Valvular Heart Disease	463 (19.7%)	399 (17.0%)	0.0186
Hypertension (complicated)	1106 (47.0%)	1161 (49.4%)	0.106
Chronic Pulmonary Disease	563 (23.9%)	629 (26.7%)	0.0275
Fluid/Electrolyte Disorder	635 (27.0%)	648 (27.6%)	0.675
Obesity	486 (20.6%)	517 (22.0%)	0.275

AMI = acute myocardial infarction. P value compares 2018 to 2019.

Table S2. Falsification Testing, Changes in Presentation, In-Hospital Treatments, and Outcomes.

Heart Failure Cohort	2018	2019	P-value
Presentation Severity			
Cardiogenic Shock	8 (0.1%)	15 (0.2%)	0.342
ED Admission	6329 (84.2%)	7176 (84.1%)	0.879
Direct Admission	1168 (15.5%)	1329 (15.6%)	0.967
Procedures and LOS			
Right Heart Catheterization	605 (8.0%)	716 (8.4%)	0.448
Length of Stay (Mean, SD)	4.78 (6.03)	4.91 (6.80)	0.189
Discharge Status			
Against Medical Advice	143 (1.9%)	173 (2.0%)	0.738
Death	163 (2.2%)	198 (2.3%)	
Home	4694 (62.5%)	5304 (62.2%)	
Home with Services	1215 (16.2%)	1374 (16.1%)	
Other	64 (0.9%)	91 (1.1%)	
Post-Acute Care	1237 (16.5%)	1392 (16.3%)	

ED = emergency department. AMA = against medical advice. P value compares 2018 to 2019.

Table S2. Falsification Testing, Changes in Presentation, In-Hospital Treatments, and Outcomes

(continued)

AMI Cohort	2018	2019	P-value
Presentation Severity			
Cardiogenic Shock	256 (10.9%)	255 (10.8%)	1.00
ED Admission	8141 (82.5%)	8975 (82.5%)	0.956
Direct Admission	1705 (17.3%)	1877 (17.2%)	0.965
NSTEMI	1668 (70.8%)	1689 (71.8%)	0.476
STEMI	687 (29.2%)	663 (28.2%)	
Procedures and LOS			
Left Heart Catheterization	1626 (69.0%)	1693 (72.0%)	0.0295
Length of Stay (Mean, SD)	5.29 (6.53)	5.05 (6.53)	0.212
Discharge Status			
Against Medical Advice	37 (1.6%)	46 (2.0%)	0.664
Death	140 (5.9%)	139 (5.9%)	
Home	1547 (65.7%)	1578 (67.1%)	
Home with Services	279 (11.8%)	262 (11.1%)	
Other	34 (1.4%)	37 (1.6%)	
Post-Acute Care	318 (13.5%)	290 (12.3%)	

AMI = acute myocardial infarction. NSTEMI = Non-ST elevation myocardial infarction. STEMI = ST elevation myocardial infarction. ED = emergency department. P value compares 2018 to 2019.