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Trends and Outcomes of Acute Myocardial Infarction During the Early COVID-19 Pandemic in the United States: A National Inpatient Sample Study

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AUTHOR'S SUMMARY

During the early period of coronavirus disease 2019 (COVID-19) pandemic in the US, trends of acute myocardial infarction (AMI) in-hospital mortality mirrored COVID-19 hospitalization surges. There was a significant decline in AMI hospitalizations and use of revascularization. AMI patients had higher in-hospital mortality and lower use of revascularization. There was also no difference in use of mechanical circulatory support devices in AMI.

ABSTRACT

Background and Objectives: There are limited national data on the trends and outcomes of patients hospitalized with acute myocardial infarction (AMI) during the coronavirus disease 2019 (COVID-19) pandemic. We aimed to evaluate the impact of early COVID-19 pandemic on the trends and outcomes of AMI using the National Inpatient Sample (NIS) database.
Methods: The NIS database was queried from January 2019 to December 2020 to identify adult (age ≥18 years) AMI hospitalizations and were categorized into ST-elevation myocardial infarction (STEMI) and non-ST-elevation myocardial infarction (NSTEMI) based on International Classification of Diseases, Tenth Revision, Clinical Modification codes. In addition, the in-hospital mortality, revascularization, and resource utilization of AMI hospitalizations early in the COVID-19 pandemic (2020) were compared to those in the pre-pandemic period (2019) using multivariate logistic and linear regression analysis.
Results: Amongst 1,709,480 AMI hospitalizations, 209,450 STEMI and 677,355 NSTEMI

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Conflict of Interest
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occurred in 2019 while 196,230 STEMI and 626,445 NSTEMI hospitalizations occurred in 2020. Compared with those in 2019, the AMI hospitalizations in 2020 had higher odds of in-hospital mortality (adjusted odds ratio [aOR], 1.27; 95% confidence interval [CI], [1.23–1.32]; p<0.01) and lower odds of percutaneous coronary intervention (aOR, 0.95 [0.92–0.99]; p=0.02), and coronary artery bypass graft (aOR, 0.90 [0.85–0.97]; p<0.01).
Conclusions: We found a significant decline in AMI hospitalizations and use of revascularization, with higher in-hospital mortality, during the early COVID-19 pandemic period (2020) compared with the pre-pandemic period (2019). Further research into the factors associated with increased mortality could help with preparedness in future pandemics.

Keywords: COVID-19; Coronavirus; Acute coronary syndromes; Myocardial infarction; Percutaneous coronary intervention

INTRODUCTION

With an estimated mortality of 1 million people in the United States, the coronavirus disease 2019 (COVID-19) pandemic strained the healthcare system and exposed its shortcomings.[1] Interactions between the pandemic and cardiovascular disease burden manifested in several ways. First, it led to recognition of COVID-19–related acute myocardial injury.[2] Second, COVID-19 mortality rates were higher among those with preexisting cardiac comorbidities.[3)4] Third, the incidence of hospital admissions for ST-segment elevation myocardial infarction (STEMI) and non-ST-segment elevation myocardial infarction (NSTEMI) decreased during the pandemic period.[5)6] Finally, due to strained healthcare resources and concern about viral transmission, there was a renewed focus on thrombolytic therapy as a primary reperfusion strategy for STEMI.[7)8] We aimed to evaluate the impact of the early COVID-19 pandemic on the trends and in-hospital outcomes of acute myocardial infarction (AMI) in a large cohort using the National Inpatient Sample (NIS) database.

METHODS

Ethical statement

All data within the NIS are publicly available and de-identified; therefore, Institutional Review Board approval was not required for our study.

Study data

We conducted a retrospective cohort study using the 2019 and 2020 NIS databases. The NIS is the largest all-payer publicly available database in the United States. It is part of the Healthcare Cost and Utilization Project (HCUP), sponsored by the Agency for Healthcare Research and Quality. The NIS database includes more than 100 clinical and nonclinical data elements equating to ~8 million unweighted hospital discharges, representing roughly 20% of hospital admissions across different hospital types and geographic regions. NIS data are used for national healthcare utilization, charges, and outcomes estimates. The database has been used to report trends, inpatient outcomes, and associated procedure utilization of AMI patients.[9] All data within the NIS are publicly available and de-identified; therefore, Institutional Review Board approval was not required for our study. We adhered to the essential elements and methodological standards recommended by the HCUP using the 'Checklist for Working with the NIS.'[10)11]

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Study population

Adult (age ≥18 years) AMI (either STEMI or NSTEMI) patients hospitalized from January 1, 2019, to December 31, 2020, were identified using the appropriate International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) codes (**Supplementary Table 1**) in the primary and secondary diagnosis sections. The cohort was categorized based on the year of hospitalization (2019 or 2020) and further stratified based on clinical presentation (STEMI 2019 vs. STEMI 2020, and NSTEMI 2019 vs. NSTEMI 2020). We also identified COVID-19 hospitalizations between January 2020 and December 2020 using ICD-10-CM codes and percutaneous coronary procedures using ICD-10-PCS codes. Furthermore, we extracted demographics, primary payer, hospital characteristics, and baseline comorbidities. Finally, we used the Charlson comorbidity index (CCI) to identify comorbidities and additional comorbidities were also utilized as mentioned in **Supplementary Table 1**.

Study outcomes

We compared the outcomes of AMI (STEMI and NSTEMI) hospitalizations for 2019 (pre-pandemic reference group) with those of 2020 (early COVID-19 pandemic group). Our primary outcome was in-hospital mortality. Secondary outcomes included the use of coronary angiography, percutaneous coronary intervention (PCI), coronary artery bypass graft (CABG), thrombolytics, and mechanical circulatory support (MCS) devices; resource utilization (total hospitalization costs and length of stay); and monthly trends of these outcomes. We also compared STEMI- and NSTEMI-associated mechanical complications (ventricular septal defect, free wall rupture, and papillary muscle rupture) between 2019 and 2020.

Statistical analysis

Categorical variables were reported as numbers with percentages and compared using Pearson's chi-squared test. In contrast, continuous variables were reported as weighted means with standard deviation or median with interquartile ranges, as appropriate for the distribution, and were compared using independent t-tests or Wilcoxon rank sum tests. For the 2020 vs. 2019 outcomes comparison, univariate logistic and linear regression were used to calculate unadjusted odds ratios (ORs) and mean difference (MD), respectively. Also, multivariate logistic and linear regression were used to calculate adjusted odds ratios (aORs) and mean difference (aMD), respectively. Covariates included in the adjusted analyses were age, sex, race, admission day, insurance status, median household income by zip code, hospital bed size, CCI, obesity, atrial fibrillation/flutter, hypertension, diabetes mellitus, chronic obstructive pulmonary disease, coronary artery disease, prior stroke, chronic kidney disease, end-stage renal disease, peripheral vascular disease, anemia, and smoking status. All analyses were conducted using appropriate stratifying, clustering, and weighting samples provided by HCUP regulations.[10] Discharge weights provided by NIS were applied for all analyses to calculate national estimates for this study. All statistical analyses were performed using the Stata software package, version 17.0 SE-Standard Edition (StataCorp, College Station, TX, USA).

RESULTS

Baseline characteristics

A total of ~1.7 million AMI adult hospitalizations were identified, of which 405,680 were STEMI and 1,303,800 were NSTEMI. Detailed baseline characteristics of the stratified AMI

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Data Sharing Statement

The data generated in this study is available from the corresponding author upon reasonable request.

Author Contributions

Conceptualization: Thyagaturu H; Formal analysis: Sandhyavenu H; Investigation: Thyagaturu H, Sandhyavenu H, Roma N; Methodology: Titus A; Supervision: Hashem A, Dawn Abbott J, Balla S, Bhatt DL; Validation: Titus A, Hashem A; Visualization: Titus A, Gonuguntla K; Writing - original draft: Thyagaturu H; Writing - review & editing: Thyagaturu H, Roma N, Gonuguntla K, Navinkumar Patel N, Hashem A, Dawn Abbott J.

groups in 2019 and 2020 are summarized in **Table 1**. The mean age for STEMI and NSTEMI was 64.2 and 68.9 years, respectively. Compared with 2019, AMI hospitalizations in 2020 had a higher proportion of home healthcare discharges (STEMI: 8.8% vs. 10.2%; NSTEMI: 14.8% vs. 16.3%; both p<0.01), and higher prevalence of obesity (STEMI: 18.2% vs. 20.6%; NSTEMI: 21.2% vs. 22.7%; both p<0.01), prior history of coronary artery disease (CAD) (STEMI: 88.3% vs. 89.3%; NSTEMI: 88.9% vs. 89.6%; both p<0.01), and heart failure (STEMI: 29.8% vs. 31.5%; NSTEMI: 44.5% vs. 45.2%; both p<0.01).

Trends in coronavirus disease 2019 hospitalization

From January 2020 to December 2020, there were 1,676,689 COVID-19 hospitalizations. On regression analysis, the overall monthly trend showed an increase in hospitalizations from January to December (85 → 338,814; p<0.01), with two significant surges, in April and December (**Figure 1**, **Supplementary Table 2**).

Trends in ST-elevation myocardial infarction hospitalizations

The volume of STEMI hospitalizations showed a significant drop in April 2020, coinciding with the first COVID-19 surge, and remained low in subsequent months of 2020 compared with 2019 (p-trend <0.01) (**Figure 2A**, **Supplementary Table 3**). However, the rate of in-hospital mortality of STEMI increased during surges in COVID-19 hospitalization (April and December 2020) (p<0.01) (**Figure 2B**, **Supplementary Table 4**). Overall trends of procedure utilization in STEMI, such as coronary angiography and PCI, were lower in 2020 than in 2019 (both p<0.01) (**Figure 2C**, **Supplementary Tables 5** and **6**). However, there was no significant trend difference in CABG use between the two years (p=0.39), despite the lower utilization of CABG during the first COVID surge (**Figure 2C**, **Supplementary Table 7**). The use of thrombolytics was similar between the two years (p=0.58), except in April and December 2020, which showed higher thrombolytic use (**Supplementary Table 8**). Similar trends were noted in the rate of mechanical complications during 2019 and 2020 (p=0.43), except in June 2020, which showed the highest mechanical complications secondary to STEMI compared with 2019 (**Supplementary Table 9**).

Trends in non-ST-elevation myocardial infarction hospitalizations

The volume of NSTEMI hospitalizations followed a similar trend to that of the STEMI group, with a significant initial drop during the first COVID-19 surge, in April 2020 (p<0.01), and remained low in subsequent months of 2020 compared with 2019 (**Figure 3A**, **Supplementary Table 3**). The in-hospital mortality trend of NSTEMI hospitalizations peaked during the first COVID surge, in April 2020, and remained high throughout the rest of the year compared with 2019 (p<0.01) (**Figure 3B**, **Supplementary Table 4**). The use of coronary angiography, PCI, and CABG in NSTEMI was lower in 2020 than in 2019, with a significant drop occurring during the first COVID-19 surge (p<0.01) (**Figure 3C**, **Supplementary Tables 5**-**7**).

Crude outcomes

On unadjusted analysis, compared with 2019, AMI hospitalizations in 2020 had significantly higher odds of mortality (9.2% vs. 7.4%; OR, 1.28 [1.24–1.32]; p<0.01), a longer length of hospitalization (MD 0.13 days [0.02–0.25]; p=0.02), and higher mean total hospitalization costs (MD $1,880 [1,084–2,675)] p<0.01) (**Table 2**). The use of coronary angiography (OR, 0.90 [0.86–0.94]; p<0.01) and PCI (OR, 0.95 [0.92–0.98]; p=0.01) was lower in 2020 than in 2019. There was no statistically significant difference in the use of CABG or MCS, or in AMI-associated mechanical complications between the two years.

Table 1. Baseline characteristics of STEMI and NSTEMI hospitalizations in 2019 and 2020

AMI (n=1,709,480)	STEMI (n=405,680)			NSTEMI (n=1,303,800)		
	2019 (n=209,450)	2020 (n=196,230)	p value	2019 (n=677,355)	2020 (n=626,445)	p value
Age (years) mean±SD	64.2±12.6	64.2±12.5	0.96	69.1±13.2	68.8±13.2	0.02
18–49	13.4	13.2		8.2	8.3	
50–64	37.9	38.2		27.2	27.7	
65–74	25.7	25.8		27.1	27.3	
>75	22.8	22.7		37.4	36.6	
Female	31.3	31.7	0.21	41.1	40.1	<0.01
Weekend hospitalization	27.8	27.9	0.67	25.6	25.4	0.30
Insurance			0.23			0.01
Medicare	49.2	49.2		66.4	65.1	
Medicaid	10.8	11.4		9.2	9.9	
Private	33.0	32.6		20.6	21.1	
Uninsured	6.9	6.7		3.7	3.8	
Hospital bed size			0.85			0.91
Small	17.2	17.9		20.8	21.2	
Medium	29.4	29.3		30.7	30.2	
Large	53.3	52.7		48.4	48.6	
Teaching/location			0.73			0.96
Rural	6.4	6.7		8.3	8.5	
Urban non-teaching	17.0	17.8		19.1	19.3	
Urban teaching	76.6	75.4		72.5	72.2	
Median household income zip code			0.06			0.05
1 ($1–24,999)	29.1	28.8		32.1	32.4	
2 ($25,000–34,999)	26.1	28.4		26.6	28.4	
3 ($35,000–44,999)	24.9	23.3		23.7	21.9	
4 (≥$45,000)	19.8	19.5		17.5	17.1	
Disposition			<0.01			<0.01
Home	66.2	64.9		52.1	50.9	
Short-term hospital	4.6	4.2		8.2	7.6	
SNF	9.4	7.9		16.8	14.7	
Home healthcare	8.8	10.2		14.8	16.3	
Race			0.72			0.75
White	74.9	74.1		72.1	71.4	
Blacks	9.3	9.7		12.6	12.7	
Hispanics	8.5	8.9		8.7	9.3	
Comorbidities						0.12
Mean CCI	2.7	2.8	<0.01	3.7	3.7	
CCI score (%)			<0.01			<0.01
1	27.8	26.5		16.0	15.5	
2	29.3	28.6		19.8	19.9	
≥3	42.8	44.8		64.1	64.5	
Hypertension	73.3	74.5	<0.01	81.4	81.1	0.20
Diabetes mellitus	34.1	34.8	0.07	44.9	45.2	0.35
Obesity	18.2	20.6	<0.01	21.2	22.7	<0.01
Obstructive sleep apnea	6.6	6.4	0.47	9.6	9.2	0.06
Atrial fibrillation/flutter	15.6	15.9	0.27	22.9	23.9	<0.01
COPD	12.6	12.7	0.76	21.5	20.7	0.01
CAD	88.3	89.3	<0.01	88.9	89.6	<0.01
Heart failure	29.8	31.5	<0.01	44.5	45.2	0.03
Prior CVA	7.2	7.1	0.29	11.9	11.8	0.42
CKD stage ≥3	14.2	14.8	0.04	29.4	29.6	0.53
End-stage renal disease	2.4	2.5	0.17	6.5	6.8	0.02
Peripheral vascular disease	18.9	19.1	0.58	26.1	25.9	0.38
Anemia	18.6	19.4	0.06	30.4	31.1	0.06
Smoker	48.9	48.7	0.69	44.4	43.6	0.05

AMI = acute myocardial infarction; CAD = coronary artery disease; CCI = Charlson comorbidity index; CKD = chronic kidney disease; COPD = chronic obstructive pulmonary disease; CVA = cerebrovascular vascular accident; NSTEMI = non–ST-segment elevation myocardial infarction; SD = standard deviation; SNF = skilled nursing facility; STEMI = ST-segment elevation myocardial infarction.

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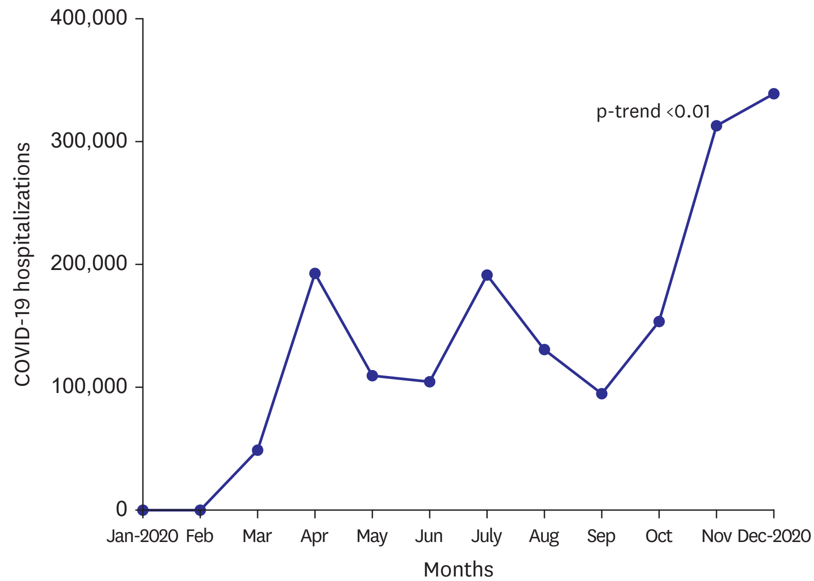

Figure 1. Trends in COVID-19 US Hospitalizations in 2020.
COVID-19 = coronavirus disease 2019.

Adjusted outcomes

On multivariate regression analysis, AMI hospitalizations showed significantly higher odds of in-hospital mortality rate (aOR, 1.27 [1.23–1.32]; p<0.01), with lower odds in the use of coronary angiography (aOR, 0.89 [0.85–0.93]; p<0.01), PCI (aOR, 0.95 [0.92–0.99]; p=0.02), and CABG (aOR, 0.90 [0.85–0.97]; p<0.01) in 2020 than in 2019. However, there was no difference in the use of MCS (aOR, 0.96 [0.91–1.02]; p=0.28) or in AMI-associated mechanical complications (aOR, 1.12 [0.87–1.43]; p=0.35) between the two years. In addition, there was a higher mean total hospitalization cost (aMD $1,653 [967–2,340]; p<0.01), with no difference in length of hospitalization (aMD 0.07; p=0.11) in 2020 vs. 2019 (**Table 2**, **Figure 4A**).

Stratified adjusted analysis based on the type of AMI presentation paralleled the overall adjusted analysis. The STEMI group had significantly higher odds of mortality (11.5% vs. 10.1%; aOR, 1.17 [1.11–1.23]; p<0.01), with lower use of coronary angiography (aOR, 0.89 [0.83–0.96]; p<0.01) and PCI (aOR, 0.94 [0.90–0.98]; p=0.02) in 2020 compared with 2019. There was no statistically significant difference in cardiogenic shock (aOR, 0.9 [0.94–1.04]); p=0.79), use of MCS (aOR, 0.96 [0.90–1.02]; p=0.22), use of thrombolytics (aOR, 0.96 [0.76–1.22]; p=0.77), mechanical complications (aOR, 1.07 [0.83–1.39]; p=0.56), or CABG use (aOR, 0.93 [0.85–1.02]; p=0.13) in the STEMI group between the two years. There were higher mean total hospitalization costs (aMD $1,531 [591–2,471]; p<0.01) with similar lengths of stay in the hospital (aMD −0.06; p=0.27) in 2020 compared with 2019 (**Table 3**, **Figure 4B**).

Similarly, the NSTEMI group had higher mortality (8.5% vs. 6.5%; aOR, 1.33 [1.28–1.37]; p<0.01), with no difference in odds of cardiogenic shock (aOR, 1.04 [0.99–1.10]; p=0.09) or the use of MCS (aOR, 0.94 [0.88–1.01]; p=0.13) in 2020 compared with 2019. The use of coronary angiography (aOR, 0.88 [0.84–0.92]; p<0.01), PCI (0.95 [0.91–0.98]; p=0.01), and CABG (aOR, 0.90 [0.84–0.97]; p<0.01) remained lower in 2020 compared with 2019. NSTEMI hospitalizations were longer (aMD 0.12 days [0.02–0.20]; p=0.02), with higher mean total hospitalization costs (aMD $1,672 USD [$1,004–$2,340]; p<0.01), in 2020 vs. 2019 (**Table 4**, **Figure 4C**).

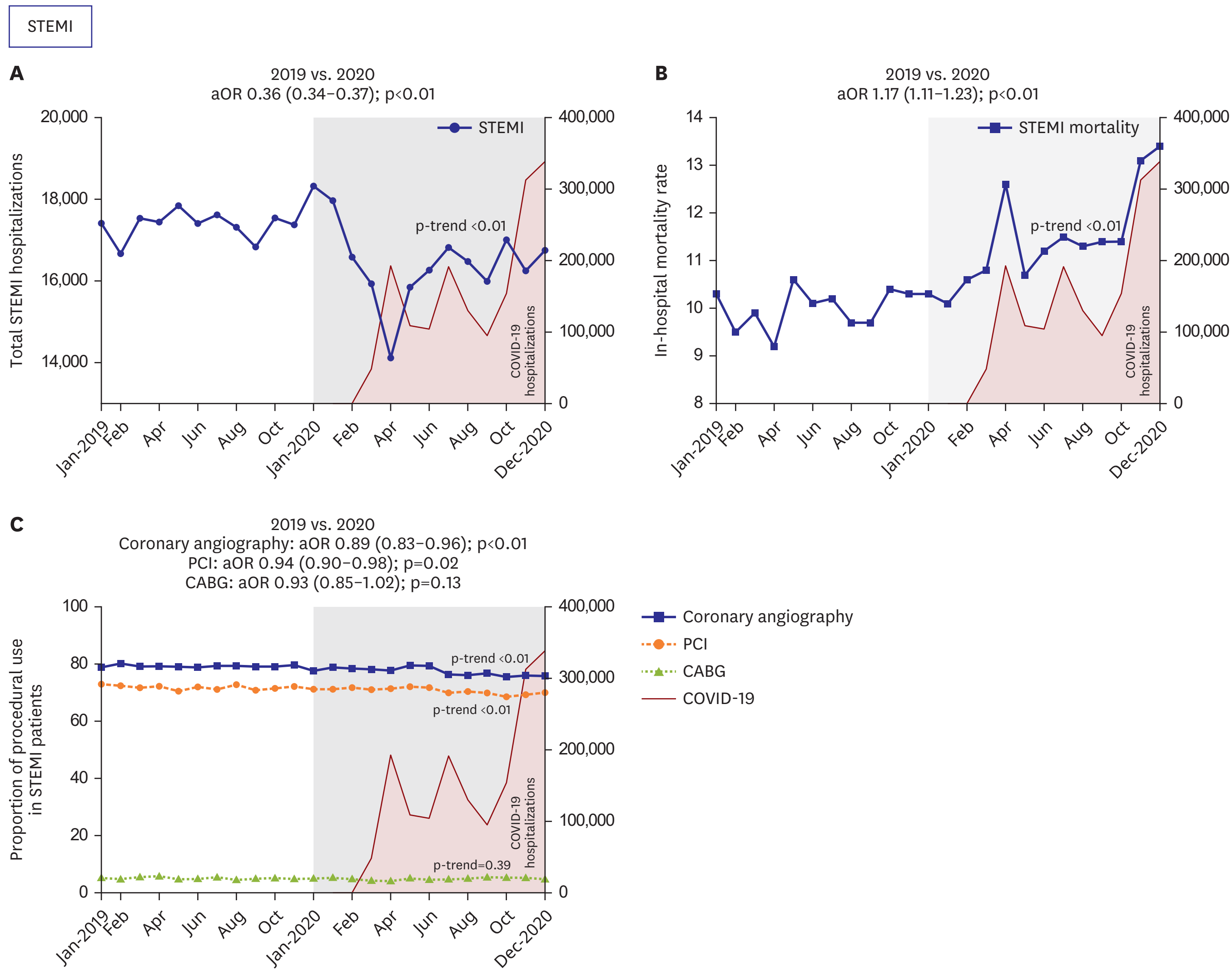

Figure 2. Trends and outcomes of STEMI hospitalizations. (A) number of STEMI hospitalizations, (B) in-hospital mortality, and (C) coronary angiography, PCI, and CABG procedure utilization.
CABG = coronary artery bypass graft; PCI = percutaneous coronary intervention; STEMI = ST-segment elevation myocardial infarction

DISCUSSION

Our large, US-based national study provides contemporary data regarding trends and outcomes of AMI hospitalizations during the early part of the COVID-19 pandemic. The key findings of our analysis are 1) The volume of AMI (STEMI and NSTEMI) hospitalizations decreased in 2020 compared with 2019, with a significant drop in April 2020 corresponding to the first surge in COVID-19 hospitalizations. 2) The trends of in-hospital mortality mirror COVID-19 hospitalization surges, with worse outcomes in April and December 2020. 3) In 2020, AMI hospitalizations had higher in-hospital mortality and lower use of revascularization procedures compared with 2019. 4) There was no statistically significant difference in rates of cardiogenic shock, mechanical complications, and use of mechanical circulatory support devices in either the STEMI or NSTEMI groups between 2020 and 2019.

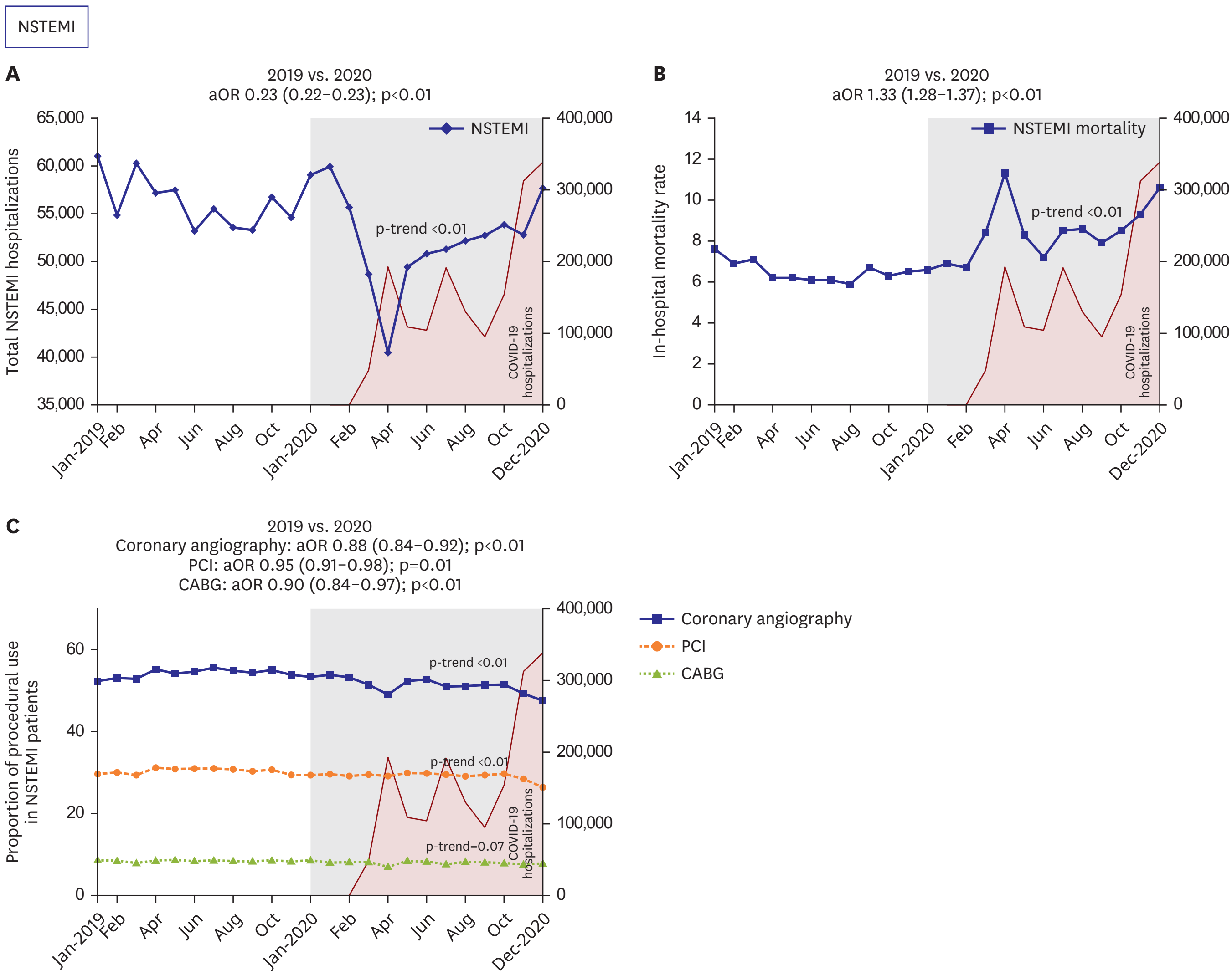

Figure 3. Trends and outcomes of NSTEMI hospitalizations (A) number of NSTEMI hospitalizations, (B) in-hospital mortality and (C) coronary angiography, PCI, and CABG procedure utilization.
CABG = coronary artery bypass graft; NSTEMI = non-ST-segment elevation myocardial infarction; PCI = percutaneous coronary intervention

Table 2. Outcomes of all acute myocardial infarction hospitalizations in 2019 vs. 2020

Outcomes	2019 (n=886,805)	2020 (n=822,674)	OR (or) MD	p value	aOR (or) aMD*	p value
In-hospital mortality	65,075 (7.4%)	75,820 (9.2%)	1.28 (1.24–1.32)	<0.01	1.27 (1.23–1.32)	<0.01
Length of stay, days (median, IQR)	3 (2–7)	3 (2–7)	0.13 (0.02–0.25)	0.02	0.07 (−0.02–0.15)†	0.11
Total hospitalization costs (USD) (mean±SD)	25,230±25,230	27,110±27,110	1,880 (1,084–2,675)	<0.01	1,653 (967–2,340)†	<0.01
Use of MCS	42,855 (4.8%)	39,125 (4.7%)	0.98 (0.92–1.04)	0.57	0.96 (0.91–1.02)	0.28
Mechanical complications	740 (<1%)	784 (<1%)	1.14 (0.89–1.45)	0.27	1.12 (0.87–1.43)	0.35
Use of coronary angiography	531,345 (60%)	472,024 (57.5%)	0.90 (0.86–0.94)	<0.01	0.89 (0.85–0.93)	<0.01
Use of PCI	355,020 (40.1%)	320,204 (39%)	0.95 (0.92–0.98)	0.01	0.95 (0.92–0.99)	0.02
Use of CABG	67,790 (7.6%)	59,309 (7.2%)	0.93 (0.87–1.00)	0.07	0.90 (0.85–0.97)	<0.01

The odds ratio and mean difference are for the year 2020 compared with 2019.
aMD = adjusted mean difference; aOR = adjusted odds ratio; CABG = coronary artery bypass graft; IQR = interquartile range; MCS = mechanical circulatory support; MD = mean difference; OR = odds ratio; PCI = percutaneous coronary intervention; SD = standard deviation.
*Variables used for adjusted analysis include age, gender, admission day, insurance status, median household income by zip code, hospital bed size, Charlson comorbidity index score, obesity, atrial fibrillation/flutter, hypertension, diabetes mellitus, chronic obstructive pulmonary disease, coronary artery disease, prior stroke, chronic kidney disease, end-stage renal disease, peripheral vascular disease, anemia, and smoking status.
†MD.

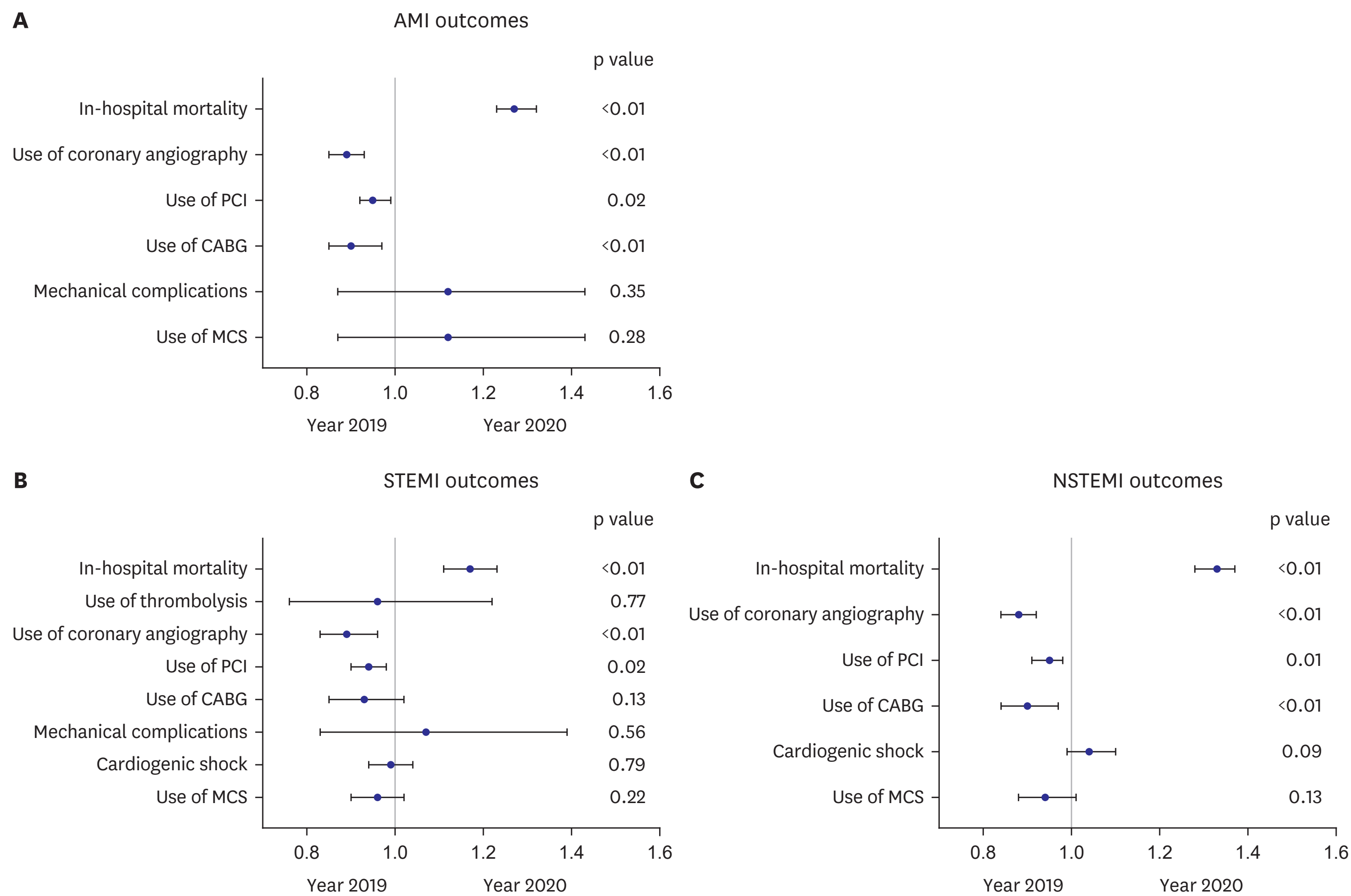

Figure 4. Forest plots showing the adjusted outcomes of (A) AMI, (B) STEMI, and (C) NSTEMI hospitalizations in 2020 vs. 2019.
AMI = acute myocardial infarction; NSTEMI = non-ST-segment elevation myocardial infarction; STEMI = ST-segment elevation myocardial infarction

Table 3. Outcomes of ST-segment elevation myocardial infarction hospitalizations in 2019 vs. 2020

Outcomes	2019 (n=209,450)	2020 (n=196,230)	OR (or) MD	p value	aOR (or) MD*	p value
In-patient mortality	21,044 (10.1%)	22,590 (11.5)	1.16 (1.10–1.22)	<0.01	1.17 (1.11–1.23)	<0.01
Length of stay, days (median) (IQR)	3 (2–5)	3 (2–5)	0.01 (−0.14–0.15)	0.96	−0.06 (−0.19–0.05)†	0.27
Total hospitalization costs (USD) (mean±SD)	29,709±34,633	31,406±37,406	1,696 (623–2,770)	<0.01	1,531 (591–2,471)†	<0.01
Cardiogenic shock	30,570 (14.6%)	28,709 (14.6%)	1.00 (0.95–1.05)	0.91	0.99 (0.94–1.04)	0.79
Use of MCS	22,065 (10.5%)	20,504 (10.4%)	0.99 (0.93–1.05)	0.77	0.96 (0.90–1.02)	0.22
Use of thrombolytics	4,350 (2.1%)	3,824 (1.9%)	0.93 (0.74–1.18)	0.59	0.96 (0.76–1.22)	0.77
Mechanical complications	640 (0.3%)	664 (0.3%)	1.10 (0.85–1.43)	0.43	1.07 (0.83–1.39)	0.56
Use of coronary angiography	165,815 (79.1%)	151,904 (77.4%)	0.90 (0.84–0.96)	<0.01	0.89 (0.83–0.96)	<0.01
Use of PCI	150,590 (71.9%)	138,559 (70.6%)	0.93 (0.89–0.98)	<0.01	0.94 (0.90–0.98)	0.02
Use of CABG	10,664 (5.1%)	9,629 (4.9%)	0.96 (0.88–1.05)	0.39	0.93 (0.85–1.02)	0.13

Odds ratio and mean difference are for the year 2020 compared with 2019.
aMD = adjusted mean difference; aOR = adjusted odds ratio; CABG = coronary artery bypass graft; IQR = interquartile range; MCS = mechanical circulatory support; MD = mean difference; OR = odds ratio; PCI = percutaneous coronary intervention; SD = standard deviation.
*Variables used for adjusted analysis include age, gender, admission day, insurance status, median household income by zip code, hospital bed size, Charlson comorbidity index score, obesity, atrial fibrillation/flutter, hypertension, diabetes mellitus, chronic obstructive pulmonary disease, coronary artery disease, prior stroke, chronic kidney disease, end-stage renal disease, peripheral vascular disease, anemia, and smoking status.
†MD.

As in other studies,[5)6)12)] we found that STEMI and NSTEMI hospitalizations decreased during the early part of the COVID-19 pandemic. In addition, a NIS based study by Chouairi et al.[12)] showed decrease in guideline directed reperfusion interventions like PCI and CABG in COVID-19 patients with AMI however, the study excluded patients with AMI in secondary

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Table 4. Outcomes of non–ST-segment elevation myocardial infarction hospitalizations in 2019 vs. 2020

Outcomes	2019 (n=677,355)	2020 (n=626,445)	OR (or) MD*	p value	aOR (or) MD*	p value
In-hospital mortality	44,295 (6.5%)	53,590 (8.5%)	1.34 (1.28–1.38)	<0.01	1.33 (1.28–1.37)	<0.01
Length of stay, days (median) (IQR)	3 (2–7)	3 (2–7)	0.18 (0.06–0.29)	<0.01	0.12 (0.02–0.20)†	0.02
Total hospitalization costs (USD) (mean ± SD)	23,876±28,697	25,807±32,985	1,931 (1,157–2,705)	<0.01	1,672 (1,004–2,340)†	<0.01
Cardiogenic shock	32,325 (4.7%)	31,530 (5%)	1.05 (1.01–1.11)	0.04	1.04 (0.99–1.10)	0.09
Use of MCS	21,015 (3.1%)	18,805 (3%)	0.96 (0.89–1.03)	0.35	0.94 (0.88–1.01)	0.13
Use of coronary angiography	366,650 (54.1%)	321,174 (51.2%)	0.89 (0.85–0.93)	<0.01	0.88 (0.84–0.92)	<0.01
Use of PCI	205,300 (30.3%)	182,459 (29.1%)	0.94 (0.91–0.98)	<0.01	0.95 (0.91–0.98)	0.01
Use of CABG	57,365 (8.4%)	49,874 (7.9%)	0.93 (0.87–1.00)	0.07	0.90 (0.84–0.97)	<0.01

Odds ratio and mean difference are for the year 2020 compared with 2019.
aMD = adjusted mean difference; aOR = adjusted odds ratio; CABG = coronary artery bypass graft; IQR = interquartile range; MCS = mechanical circulatory support; MD = mean difference; OR = odds ratio; PCI = percutaneous coronary intervention; SD = standard deviation.
*Variables used for adjusted analysis include age, gender, admission day, insurance status, median household income by zip code, hospital bed size, Charlson comorbidity index score, obesity, Atrial fibrillation/flutter, hypertension, diabetes mellitus, chronic obstructive pulmonary disease, coronary artery disease, prior stroke, chronic kidney disease, end-stage renal disease, peripheral vascular disease, anemia, and smoking status
†MD.

diagnosis section. Previous observational studies have noted an almost 38% reduction in STEMI catheterization laboratory activations during the early months of the pandemic in 2020 compared with pre-pandemic years in the United States. The reasons for the reduced incidence of AMI during the COVID-19 pandemic remain unclear.[13] Whether this reflects an actual reduction in the incidence of AMI or the occurrence of unrecognized AMI events due to fatal presentations such as out-of-hospital cardiac arrests needs further exploration.[14][15]

Our study reports increased in-hospital mortality for STEMI and NSTEMI during the early pandemic period (2020). The increased mortality could be ascribed to the lower rates of diagnostic angiography and revascularization procedures. However, multiple factors are likely at play at the patient and systems levels, both pre-hospital and in-hospital. Patients may have delayed seeking medical care due to apprehension about acquiring COVID-19 infection.[16] At a systems level, delayed emergency medical service responses were noted during the pandemic.[17] Furthermore, health systems reallocated resources to address the unprecedented surge in hospitalizations due to COVID-19. In addition, access to care was curtailed during the extended lockdown period, with the cancellation of outpatient clinic visits and procedures.[7] Delays in reperfusion after arriving at the hospital due to longer ER wait times, changes in institutional STEMI protocols, and institutional requirement of COVID-19 testing before catheterization were likely contributory. Indeed, studies have reported significantly increased door-to-balloon times during the pandemic.[18][19] This is also supported by an magnetic resonance imaging study in STEMI patients that showed larger infarct size and higher rates of microvascular obstruction and intramyocardial hemorrhage during the pandemic compared with pre-pandemic levels.[20] In our study, despite lower rates of revascularization and increased mortality, we did not find any difference in the incidence of cardiogenic shock and mechanical complications during the early pandemic period. Further, the aOR for mortality was much higher for NSTEMI compared with the STEMI group (**Tables 3** and **4**). This higher mortality in NSTEMI group could be attributed to their delayed presentation to the hospital due to less severe symptoms, lower priority for urgent revascularization, and misdiagnosis of troponin elevation in NSTEMI as type 2 myocardial infarction.[21]

On trend analysis, the increase in COVID-19 hospitalizations corresponded to a decline in AMI hospitalizations, an increase in AMI in-hospital mortality, and lower rates of diagnostic and revascularization procedures (**Figures 2** and **3**). The shift to thrombolytics for reperfusion noted during the COVID-19 surge was presumably an effort to address the anticipated procedural delays and lower the risk to healthcare professionals.[20] Further, June

2020 revealed an increased incidence of mechanical complications, which could be attributed to the first surge in COVID-19 hospitalizations and thrombolytic therapy in April 2020 (**Supplementary Tables 8** and **9**).

Our study sheds light on an important stage of the COVID-19 pandemic in the United States, and our findings could improve our preparedness for future pandemics. However, a medical revolution, including easy and affordable access to medical care during pandemics, is needed to address barriers to acute cardiovascular care in US hospitals.[22] The long-term outcomes of those treated for AMI during the pandemic also need further study.

One of the important unique features of our study is that we examined the outcomes of AMI (STEMI and NSTEMI) regardless of the concurrent COVID-19 infection status in our study group. Several studies have examined the AMI outcomes with concurrent COVID-19 infection and compared them with AMI patients without concurrent COVID infection.[23][24] Our study's main objective was to assess the in-hospital mortality, resource, and procedural utilization during COVID-19 pandemic and hence, our primary analysis did not account for COVID-19 infection status within our patient population. However, authors do recognize that COVID-19 infection played a major role in the outcomes of AMI and would be a major confounding factor. Hence, we performed a sensitivity analysis with pre-specified subgroup of COVID-19 infection status in AMI hospitalizations. Another unique aspect of our analysis was that we used both primary and secondary diagnosis coding sections within the NIS dataset to identify AMI (STEMI or NSTEMI) hospitalizations. This to be inclusive of patient population who are admitted with primary medical problem (for example, sepsis, infection) and secondarily develops AMI during hospitalization. Authors felt that including these patients will give a complete picture of the impact of COVID-19 pandemic on the in-patient treatment strategies driving all types of AMI patients. There is very limited data on STEMI related mechanical complications, use of mechanical circulatory support. Ahlers et al.,[25] investigated MCS but they had smaller population of 400+ using National Cardiogenic Shock Initiative registry. Mechanical complications were similar before and during outbreak response in a single center study from Singapore, consistent with our study reuslts.[26] Use of procedures has been investigated in terms of time to PCI but not the actual use of the procedure itself.[27]

Our study has several limitations. First, it relies on the accurate billing of appropriate ICD-10 codes. However, ICD codes of AMI have been validated to accurately identify patients with AMI with specificity as high as 99%.[28][29] Second, given the nature of retrospective studies, there remains a potential for bias due to unmeasurable confounding factors, despite adjustment for baseline comorbidities. Third, our study includes only hospitalized patients. Therefore, our results do not reflect all patients with AMI in the community. Fourth, we don't have the data points to identify time from symptom onset to hospital visit and this could be a crucial information that could play a major role in system-based reasons behind the impact of COVID-19 pandemic on AMI outcomes. Fifth, our study did not exclude AMI patients with concomitant COVID-19. Hence, it is difficult to ascertain if the worse outcomes seen in the AMI population were a direct result of COVID-19 infection, or due to external factors such as the timing of PCI, delays in reperfusion, or changes in STEMI and NSTEMI protocols. To address this issue, we performed a sensitivity analysis for our primary mortality outcome in the AMI population. Results including and excluding concomitant COVID-19 infection in the AMI population were not meaningfully different compared to our primary analysis (**Supplementary Table 10**). Thus, we reported results without excluding COVID-19 infection in the AMI population. Nevertheless, the large number of patients powers our study to determine the impact of the COVID-19 pandemic on the outcomes of AMI hospitalizations in the United States. The proportions of PCI and coronary angiography during pre-pandemic era (2019) is comparable to other National Inpatient Sample studies.[30] However, it is important to note that our study included the secondary STEMI, NSTEMI diagnoses within the study population. This is because to assess the full spectrum effects of COVID-19 pandemic on AMI population's outcomes, especially the resource utilization outcomes, the authors felt it is important to include patient population who are not only admitted primarily with AMI but also admitted patients admitted with primary medical problems (for example, sepsis, infection) and subsequently developing AMI the same hospitalization. Finally, linear regression lacks the ability to observe changes before and after COVID since it includes datapoints from before the COVID pandemic. To overcome this limitation, we performed additional Joinpoint analysis which incorporates change point analysis. The results of which did not differ in a meaningful way and remained consistent in terms of statistical significance across different subgroups and hence, retained the linear regression output in the primary analysis. However, we provided the Joinpoint analysis information including the Joinpoint regression graphs and Monthly Percentage Change data points and parameter estimates in **Supplementary Data 1**.

The COVID-19 pandemic adversely affected AMI patients' clinical outcomes, including STEMI and NSTEMI. Despite lower hospitalizations of people with AMI in 2020, we report higher in-hospital mortality rates along with lower rates of diagnostic (coronary angiography) and revascularization (PCI and CABG) procedures, suggesting a nationwide hospital system–based problem and pandemic underpreparedness. Adhering to the standards of care for treating AMI was likely challenging amidst an already overwhelmed healthcare system. The aftereffects of the pandemic on cardiovascular morbidity remain to be determined. Further studies must evaluate strategies to deliver quality cardiovascular care during future pandemics.

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SUPPLEMENTARY MATERIALS

Supplementary Table 1
ICD-10 codes for cohort identification and stratification with major baseline comorbidities

Supplementary Table 2
Total COVID-19 hospitalizations in 2020 by month

Supplementary Table 3
Acute myocardial infarction hospitalizations in 2019 and 2020 by month

Supplementary Table 4
In-patient mortality in acute myocardial infarction patients in 2019 and 2020 by month

Supplementary Table 5

Cardiac procedure volume in AMI patients in 2019 and 2020 by month: coronary angiography use in AMI

Supplementary Table 6

Cardiac procedure volume in AMI patients in 2019 and 2020 by month: percutaneous coronary intervention use in AMI

Supplementary Table 7

Cardiac procedure volume in AMI patients in 2019 and 2020 by month: coronary artery bypass graft use in AMI

Supplementary Table 8

Thrombolysis use in STEMI patients

Supplementary Table 9

Mechanical complications in STEMI patients

Supplementary Table 10

Sensitivity analysis: outcomes of all acute myocardial infarction hospitalizations by COVID status

Supplementary Data 1

Joinpoint analysis for AMI trends along with mortaliy and revascularization trends from January 2019 to December 2020.

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