JAMA | Original Investigation

Association Between COVID-19 Diagnosis and In-Hospital Mortality in Patients Hospitalized With ST-Segment Elevation Myocardial Infarction

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IMPORTANCE There has been limited research on patients with ST-segment elevation myocardial infarction (STEMI) and COVID-19.

OBJECTIVE To compare characteristics, treatment, and outcomes of patients with STEMI with vs without COVID-19 infection.

DESIGN, SETTING, AND PARTICIPANTS Retrospective cohort study of consecutive adult patients admitted between January 2019 and December 2020 (end of follow-up in January 2021) with out-of-hospital or in-hospital STEMI at 509 US centers in the Vizient Clinical Database (N = 80 449).

EXPOSURES Active COVID-19 infection present during the same encounter.

MAIN OUTCOMES AND MEASURES The primary outcome was in-hospital mortality. Patients were propensity matched on the likelihood of COVID-19 diagnosis. In the main analysis, patients with COVID-19 were compared with those without COVID-19 during the previous calendar year.

RESULTS The out-of-hospital STEMI group included 76 434 patients (551 with COVID-19 vs 2755 without COVID-19 after matching) from 370 centers (64.1% aged 51-74 years; 70.3% men). The in-hospital STEMI group included 4015 patients (252 with COVID-19 vs 756 without COVID-19 after matching) from 353 centers (58.3% aged 51-74 years; 60.7% men). In patients with out-of-hospital STEMI, there was no significant difference in the likelihood of undergoing primary percutaneous coronary intervention by COVID-19 status; patients with in-hospital STEMI and COVID-19 were significantly less likely to undergo invasive diagnostic or therapeutic coronary procedures than those without COVID-19. Among patients with out-of-hospital STEMI and COVID-19 vs out-of-hospital STEMI without COVID-19, the rates of in-hospital mortality were 15.2% vs 11.2% (absolute difference, 4.1% [95% CI, 1.1%-7.0%]; $P = .007$). Among patients with in-hospital STEMI and COVID-19 vs in-hospital STEMI without COVID-19, the rates of in-hospital mortality were 78.5% vs 46.1% (absolute difference, 32.4% [95% CI, 29.0%-35.9%]; $P < .001$).

CONCLUSIONS AND RELEVANCE Among patients with out-of-hospital or in-hospital STEMI, a concomitant diagnosis of COVID-19 was significantly associated with higher rates of in-hospital mortality compared with patients without a diagnosis of COVID-19 from the past year. Further research is required to understand the potential mechanisms underlying this association.

Editorial

Supplemental content

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JAMA. doi:10.1001/jama.2021.18890
Published online October 29, 2021.

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The COVID-19 pandemic has negatively affected the care of patients with ST-segment elevation myocardial infarction (STEMI). The number of patients presenting with STEMI declined substantially during pandemic surges,[1,2] reperfusion strategies were modified,[3,4] and delays in reperfusion were observed around the world.[3-5] Poorer STEMI-related outcomes have been reported throughout the pandemic, including higher rates of in-hospital mortality.[3,5] Whether these outcomes have been the result of pandemic-related factors or SARS-CoV-2 infection is unclear. Data from relatively small cohort studies suggest that outcomes following out-of-hospital STEMI may be worse among those with COVID-19 than among those without COVID-19,[6-8] but few broadly representative data exist. Few data characterizing acute in-hospital STEMI among patients hospitalized with COVID-19 exist.[9,10]

To better understand the association between COVID-19 and STEMI outcome in a large, nationally representative patient cohort, the present study used a multicenter clinical database to assess patients with COVID-19 vs those without COVID-19 who presented with out-of-hospital STEMI or developed STEMI while hospitalized. To differentiate between the direct- and pandemic-related association between COVID-19 and clinical outcome, separate control patients from the same year and the past year were used when comparing patients with vs without a COVID-19 diagnosis.

Key Points

Question In patients with ST-segment elevation myocardial infarction (STEMI), is a concomitant diagnosis of COVID-19 associated with differences in clinical outcome?

Findings In this retrospective cohort study that included 80 449 patients, the rates of in-hospital mortality for patients with vs without a concomitant diagnosis of COVID-19 were 15.2% vs 11.2% among those with out-of-hospital STEMI and 78.5% vs 46.1% among those with in-hospital STEMI; both differences were statistically significant.

Meaning Among patients with STEMI, a concomitant diagnosis of COVID-19 was associated with significantly higher rates of in-hospital mortality.

Methods

Study Approval

This study was deemed exempt from the requirements of 45 CFR 46.104(d) by The Miriam Hospital Institutional Review Board given that it involved deidentified data.

Data Source

The Vizient Clinical Database gathers demographic, comorbid, clinical outcome, resource, cost, and readmission data from patients hospitalized at each of its 757 US academic medical centers and affiliated hospitals in 50 states. The distribution of admissions in these centers in 2020 was as follows: 28% from the Midwest, 24.6% from the Northeast, 31.2% from the South, and 16.1% from the West. All data were deidentified prior to extraction.

Study Population

Patients who were hospitalized with STEMI at a percutaneous coronary intervention (PCI)-capable center between January 1, 2019, and December 31, 2020, were included. Patients who presented to non-PCI-capable centers may have entered the analysis if they were subsequently transferred to a PCI-capable center. Exclusion criteria appear in **Figure 1**. Patients who were transferred into or out from the index hospital were not excluded from the main analyses. Deidentified data do not include individual patient age, so mean/median age could not be calculated, but age is reported as age groupings. Race and ethnicity were included among patient baseline characteristics because both are associated with outcomes in patients with STEMI and COVID-19 infection.[11,12] Fixed race and ethnicity categories exist in the database and are determined at each hospital by patient self-report. STEMI diagnosis, comorbidities, and treatments rendered were ascertained using *International Classification of Diseases, Tenth Revision* (*ICD-10*) diagnostic and procedure codes (eTable 1 in the Supplement). Prior validation literature for the utilized *ICD-10* codes is provided in the eMethods in the Supplement. The Centers for Medicare & Medicaid Services' "present on admission" indicator was used to differentiate preexisting from incident conditions.[13] The Elixhauser comorbidity score incorporates 30 comorbid conditions, with higher scores reflecting greater risk of in-hospital mortality[14]; the score was determined for each patient in the database and provided for this analysis (eMethods in the Supplement).

Two nonoverlapping study groups were defined. Both included consecutive patients 18 years or older. The first group (out-of-hospital group) included those in whom STEMI was present on admission, defined by both a principal diagnosis of STEMI and a STEMI present on admission indicator ("Y"). The second group (in-hospital group) included those who experienced STEMI during hospitalization, defined by a diagnosis of STEMI that was neither the principal diagnosis nor present on admission.

Exposure

Active COVID-19 infection was defined as presence of the *ICD-10* code U071 during the same encounter.

Outcomes

The primary outcome of interest was all-cause in-hospital mortality. Secondary outcomes included in-hospital composite death, recurrent MI or stroke, composite death or stroke, new acute decompensated heart failure, and cardiogenic shock. In-hospital exploratory outcomes included mechanical complications, bleeding, blood transfusion, acute kidney injury, need for mechanical ventilation, encephalopathy, septic shock, pneumonitis, acute respiratory failure, length of stay (overall and intensive care unit), hospitalization cost, and discharge disposition. The only postdischarge outcome available was 30-day readmission. Outcomes defined using *ICD-10* codes appear in eTable 1 in the Supplement.

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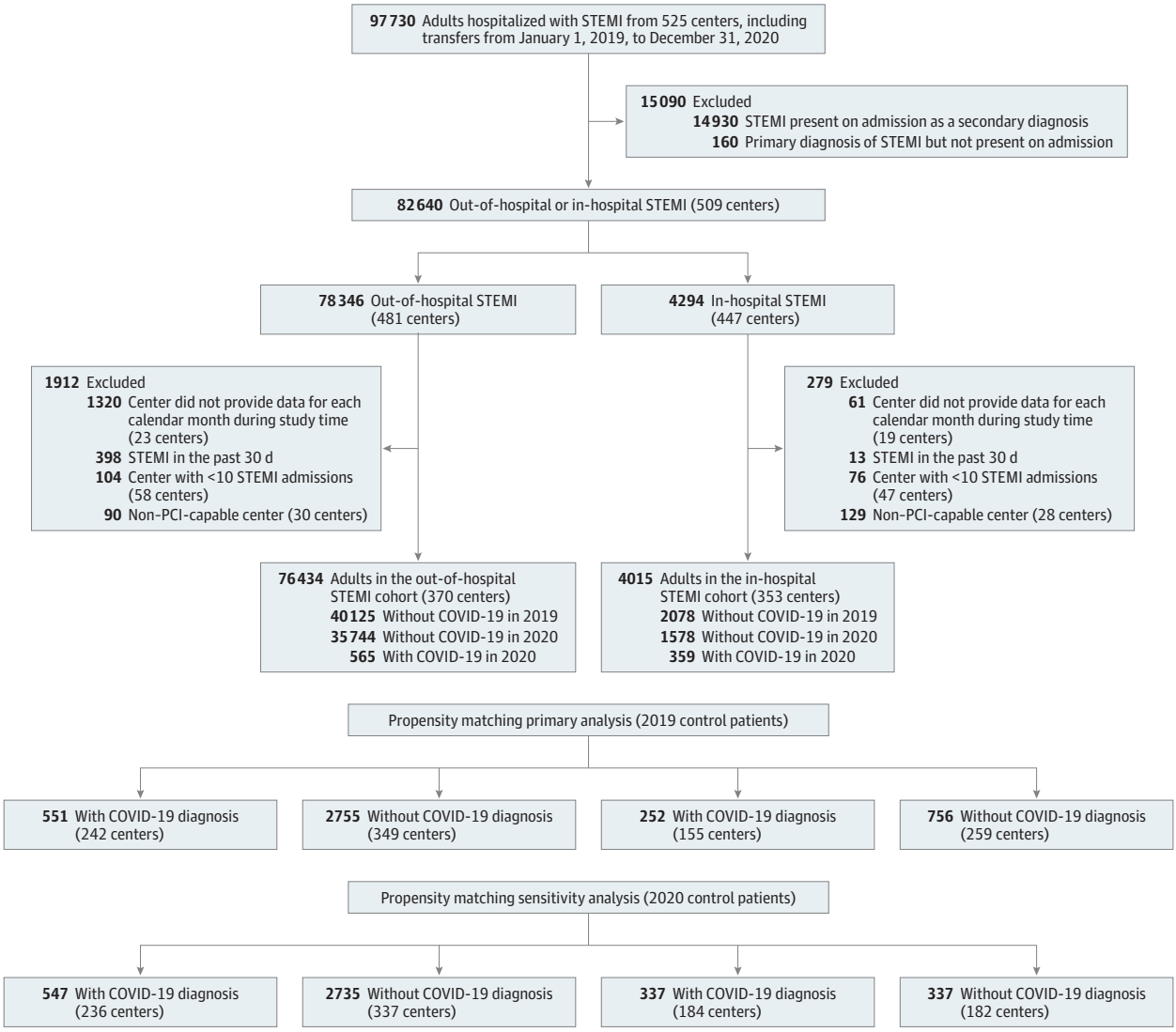
Figure 1. Study Flow and Matching of Patients With ST-Segment Elevation Myocardial Infarction (STEMI) With or Without COVID-19



Out-of-hospital STEMI was defined through *International Classification of Diseases, Tenth Revision* coding (see eTable 1 in the Supplement) as being both present on admission and the primary diagnosis, while in-hospital STEMI was defined as nonprimary diagnosis coding and not present on admission. Patients in whom these were mixed (eg, STEMI present on admission but not the primary diagnosis) were excluded. Patients who presented to centers not capable of percutaneous coronary intervention (PCI), and were therefore excluded, may have entered the analysis if they subsequently transferred to a PCI-capable center.

Statistical Analysis

Continuous variables are presented as mean and SD values or median and interquartile range values, depending on their distribution, and were compared using *t* tests and Wilcoxon rank-sum tests, respectively. Categorical variables are presented as frequencies and percentages and were compared using χ^2 tests. Multivariable logistic regression incorporating demographic, clinical, and facility characteristics was used to develop a propensity score on which those without COVID-19 were matched to those with COVID-19. Only main effects were entered in the models. A full list of variables included in the propensity models appear in the eMethods in the Supplement. To maximize group size, matching was performed at 5:1 for the out-of-hospital group and 3:1 for the in-hospital group. Nearest-neighbor matching with a caliper width of 0.2 times the pooled SD of the logit was used[15]; in the out-of-hospital group, patients were matched within 4 weeks of the admission date to account for potential seasonal variation. Standardized differences were used to assess the effectiveness of the match, with values less than 10% suggesting well-balanced groups on a given covariate. In the main analyses, patients with out-of-hospital or in-hospital STEMI and COVID-19 were compared with those with STEMI without COVID-19 during the same months of the previous calendar year; the rationale for selecting the comparison group from the past year was to try to remove the influence

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of pandemic-related factors from the analysis. A 2-sided *P* value <.05 was considered statistically significant. To maximize the number of eligible patients available for matching, simple imputation was used for variables with missing data, using the most frequently observed category among those with nonmissing values (eResults in the Supplement). Because of the potential for type I error due to multiple comparisons, findings of analyses of secondary end points should be interpreted as exploratory. All analyses were performed with SAS, version 9.4 (SAS Institute).

Sensitivity analyses for the primary end point were conducted separately in the out-of-hospital and in-hospital STEMI group, each comparing patients with a COVID-19 diagnosis to propensity-matched patients without a COVID-19 diagnosis. First, the control group comprised patients admitted during the same (rather than previous) calendar year; the rationale for doing so was to incorporate secular factors (eg, differences in hospital resource availability during the pandemic) as well as the pathophysiological effect of COVID-19 on outcomes after STEMI. Second, the control group patients were matched to the exposed group on center. Third, patients who were transferred from one hospital to another were excluded. Fourth, multivariable regression was used following propensity-score matching to generate the least biased and most efficient estimates possible. Variables included in multivariable regression analysis are summarized in the eMethods in the Supplement.

Results

Among 97 730 patients hospitalized with STEMI at 525 centers during the study period, 82 640 from 509 centers met the study definition of out-of-hospital (n = 78 346; 481 centers) or in-hospital (n = 4294; 447 centers) STEMI. After applying exclusion criteria, the final out-of-hospital STEMI group included 76 434 patients and the in-hospital STEMI group included 4015 patients (Figure 1; **Table 1** and **Table 2**). Of 20 variables used for propensity matching and multivariable regression, only 6 (all categorical) had missing data (eResults in the Supplement).

Out-of-Hospital STEMI

Study Population

Baseline characteristics of patients with vs without COVID-19 and out-of-hospital STEMI are summarized in Table 1. Characteristics that were not well matched are specified in the eMethods in the Supplement. Standardized mean differences for patient characteristics appear in the eMethods in the Supplement. Across 370 centers, 565 patients were admitted with out-of-hospital STEMI and diagnosed with COVID-19 during the same encounter. During the same months in 2019 and 2020, a total of 75 869 patients (40 125 in 2019 and 35 744 in 2020) were admitted with out-of-hospital STEMI in whom a COVID-19 diagnosis was not present. When comparing patients with vs those without COVID-19, age and sex (69.9% vs 70.3% men; *P* = .85) were not significantly different, but those with COVID-19 were significantly less likely to be White (62.4% vs 76.3%; *P* < .001) and significantly more likely to be Hispanic (21.8% vs 8%; *P* < .001). Multiple comorbidities were prevalent in patients with COVID-19, reflected by a significantly higher median (IQR) Elixhauser comorbidity score than those without COVID-19 (2.0 [1.0-3.0] vs 1.0 [1.0-3.0]; *P* < .001). Patients with COVID-19 were significantly more likely to present with cardiac arrest (10.3% vs 6.8%; *P* = .001).

Treatment Characteristics

Although fibrinolytic therapy as standalone therapy was used in a minority of patients, those with COVID-19 were significantly more likely to receive this treatment than patients without COVID-19 (1.9% vs 0.2%; *P* < .001). Coronary angiography was performed significantly less often in patients with COVID-19 (81.9% vs 86.2%; *P* = .003), but the rates of primary PCI (71.0% vs 74.3%; *P* = .07), any PCI (79.8% vs 81.8%; *P* = .22), and coronary artery bypass grafting (3.5% vs 5.2%; *P* = .07) during the index encounter were not significantly different between groups. The use of mechanical circulatory support was also not significantly different between the groups (11.0% vs 10.1%; *P* = .50).

Primary Outcome

The unadjusted primary outcome in patients with vs without COVID-19 and out-of-hospital STEMI is summarized in eTable 2 and eFigure 1 in the Supplement. The propensity-matched primary outcome is shown in **Figure 2**. Patients with COVID-19 vs without COVID-19 had significantly higher rates of in-hospital mortality (15.2% vs 11.2%; absolute difference, 4.1% [95% CI, 1.1% to 7.0%]; odds ratio [OR], 1.43 [95% CI, 1.1-1.86]; *P* = .007) (Figure 2).

Secondary Outcomes

Unadjusted secondary outcomes in patients with vs without COVID-19 and out-of-hospital STEMI are summarized in eTable 2 and eFigure 1 in the Supplement. Propensity-matched secondary outcomes are shown in Figure 2. Patients with COVID-19 vs without COVID-19 had significantly higher rates of composite death, MI, or stroke (18.0% vs 13.2%; absolute difference, 4.8% [95% CI, 1.6%-7.9%]; *P* = .003) and composite death or stroke (18.0% vs 13.1%; absolute difference, 4.8% [95% CI, 1.7%-8.0%]; *P* = .002); other secondary outcomes were not significantly different between the groups (Figure 2).

Exploratory Outcomes

Unadjusted and propensity-matched exploratory outcomes in patients with vs without COVID-19 and out-of-hospital STEMI are summarized in eTables 2 and 3 in the Supplement.

Sensitivity Analyses

In sensitivity analyses, rates of in-hospital mortality remained significantly higher in patients with COVID-19 compared with a control group from the same calendar year (ie, 2020) (15.4% vs 11.1%; absolute difference, 4.3% [95% CI, 1.1%-7.5%]; OR, 1.46 [95% CI, 1.12-1.89]; *P* = .004) (eTable 4 in the Supplement), a control group matched on center (15.0% vs 8.6%; absolute difference, 6.4% [95% CI, 2.1%-10.6%],

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Table 1. Demographic, Clinical, and Treatment Characteristics in Unmatched and Propensity-Matched Patients With Out-of-Hospital STEMI[a]

Characteristic	Unmatched groups			Propensity-matched groups		
	Patients, No. (%)			Patients, No. (%)		
	With COVID-19 (n = 565)	Without COVID-19 (n = 75 869)	Standardized difference	With COVID-19 (n = 551)	Without COVID-19 (n = 2755)	Standardized difference
Patient demographics						
Age, y						
31-50	90 (15.9)	12 049 (15.9)		86 (15.6)	446 (16.2)	
51-64	208 (36.8)	29 371 (38.7)		206 (37.4)	997 (36.2)	
65-74	158 (28.0)	19 262 (25.4)	.09	152 (27.6)	774 (28.1)	.05
75-79	49 (8.7)	6110 (8.1)		48 (8.7)	261 (9.5)	
80-84	27 (4.8)	4260 (5.6)		27 (4.9)	126 (4.6)	
85-89	16 (2.8)	2866 (3.8)		15 (2.7)	80 (2.9)	
≥90	17 (3.0)	1951 (2.6)		17 (3.1)	71 (2.6)	
Sex						
Men	395 (69.9)	53 321 (70.3)	.008	385 (69.9)	1939 (70.4)	.01
Women	170 (30.1)	22 548 (29.7)		166 (30.1)	816 (29.6)	
Race[b]	(n = 537)	(n = 73 836)		(n = 551)	(n = 2755)	
Asian	16 (3.0)	2264 (3.1)		16 (2.9)	111 (4.0)	
Black	90 (16.8)	8447 (11.4)	.33	85 (15.4)	428 (15.5)	.09
White	335 (62.4)	56 369 (76.3)		354 (64.2)	1781 (64.6)	
Other	96 (17.8)	6756 (9.1)		96 (17.4)	435 (15.8)	
Hispanic ethnicity[b]	109 (21.8)	5508 (8.0)	.39	108 (19.6)	546 (19.8)	.005
Admission source						
Non-health care facility[c]	374 (66.2)	51 391 (67.7)		366 (66.4)	1919 (69.7)	
Transfer from another facility	136 (24.1)	17 766 (23.4)		135 (24.5)	594 (21.6)	
Transfer from a skilled nursing facility or intermediate care facility	32 (5.7)	1963 (2.6)	.19	29 (5.3)	59 (2.1)	.23
Clinic referral	15 (2.7)	3854 (5.1)		14 (2.5)	143 (5.2)	
Law enforcement/court, other transfer, or not available[d]	8 (1.4)	895 (1.2)		7 (1.3)	40 (1.5)	
Payer						
Medicare	230 (40.7)	33 687 (44.4)		223 (40.5)	1131 (41.1)	
Private	168 (29.7)	25 693 (33.9)	.19	164 (29.8)	801 (29.1)	.02
Medicaid	97 (17.2)	8745 (11.5)		96 (17.4)	480 (17.4)	
Other[e]	70 (12.4)	7744 (10.2)		68 (12.3)	343 (12.5)	
Cardiovascular comorbidities						
Prior coronary artery disease	485 (85.8)	67 334 (88.8)	.09	472 (85.7)	2408 (87.4)	.05
Hypertension	447 (79.1)	56 726 (74.8)	.10	435 (78.9)	2207 (80.1)	.03
Hyperlipidemia	373 (66.0)	50 956 (67.2)	.02	364 (66.1)	1845 (67.0)	.02
Diabetes	271 (48.0)	25 712 (33.9)	.29	263 (47.7)	1345 (48.8)	.02
Obesity	144 (25.5)	16 287 (21.5)	.09	140 (25.4)	721 (26.2)	.02
Heart failure on admission	99 (17.5)	14 928 (19.7)	.06	93 (16.9)	460 (16.7)	.005
Smoking	90 (15.9)	24 009 (31.6)	.38	89 (16.2)	451 (16.4)	.006
Cardiac arrest on admission	58 (10.3)	5162 (6.8)	.12	56 (10.2)	254 (9.2)	.03
Cerebrovascular disease	40 (7.1)	4068 (5.4)	.07	39 (7.1)	189 (6.9)	.009
Prior stroke	38 (6.7)	4653 (6.1)	.02	34 (6.2)	223 (8.1)	.08
Valvular heart disease	30 (5.3)	4957 (6.5)	.05	30 (5.4)	136 (4.9)	.02
Prior CABG	17 (3.0)	2996 (3.9)	.05	15 (2.7)	72 (2.6)	.007
Prior coronary intervention	4 (0.7)	874 (1.2)	.05	3 (0.5)	31 (1.1)	.06
Prior myocardial infarction	1 (0.2)	120 (0.2)	.005	0	2 (0.1)	.04

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Table 1. Demographic, Clinical, and Treatment Characteristics in Unmatched and Propensity-Matched Patients With Out-of-Hospital STEMI[a] (continued)

Characteristic	Unmatched groups			Propensity-matched groups		
	Patients, No. (%)			Patients, No. (%)		
	With COVID-19 (n = 565)	Without COVID-19 (n = 75 869)	Standardized difference	With COVID-19 (n = 551)	Without COVID-19 (n = 2755)	Standardized difference
Other comorbidities						
Chronic anemia	146 (25.8)	14 722 (19.4)	.15	140 (25.4)	701 (25.4)	.001
Chronic kidney disease	117 (20.7)	11 924 (15.7)	.13	111 (20.1)	561 (20.4)	.005
Coagulopathy	79 (14.0)	6381 (8.4)	.18	75 (13.6)	355 (12.9)	.02
COPD	66 (11.7)	11 300 (14.9)	.09	64 (11.6)	315 (11.4)	.06
Chronic liver disease	40 (7.1)	5542 (7.3)	.009	38 (6.9)	198 (7.2)	.01
Pulmonary circulation disorder	24 (4.2)	2950 (3.9)	.02	22 (4.0)	105 (3.8)	.009
End-stage kidney disease	19 (3.4)	1347 (1.8)	.01	18 (3.3)	87 (3.2)	.006
Elixhauser comorbidity score, median (IQR)[f]	2.0 (1.0-3.0)	1.0 (1.0-3.0)	.19	2.0 (1.0-3.0)	2.0 (1.0-3.0)	.001
Facility characteristics						
Beds						
0-150	127 (23.0)	16 741 (22.7)		126 (22.9)	619 (22.5)	
151-250	42 (7.6)	6949 (9.4)	.07	42 (7.6)	203 (7.4)	.02
251-500	112 (20.3)	15 468 (20.9)		112 (20.3)	568 (20.6)	
>500	271 (49.1)	34 699 (47.0)		271 (49.2)	1365 (49.5)	
Urban[g]	539 (97.6)	71 611 (97.0)	.04	538 (97.6)	2682 (97.4)	.02
Region						
Midwest	177 (33.8)	22 138 (31.0)		176 (31.9)	855 (31.0)	
Northeast	164 (31.4)	21 157 (29.6)	.23	193 (35.0)	961 (34.9)	.03
Southeast	71 (13.6)	15 140 (21.2)		71 (12.9)	378 (13.7)	
Southwest	57 (10.9)	5100 (7.1)		57 (10.3)	290 (10.5)	
West	54 (10.3)	7897 (11.1)		54 (9.8)	271 (9.8)	
Ownership[h]						
Voluntary	449 (81.3)	59 693 (80.8)		448 (81.3)	2265 (82.2)	
Governmental	86 (15.6)	11 416 (15.5)	.04	86 (15.6)	408 (14.8)	.02
Proprietary	17 (3.1)	2748 (3.7)		17 (3.1)	82 (3.0)	
No. of patients with STEMI treated per year, mean						
≤50	37 (6.5)	2822 (3.7)		35 (6.4)	169 (6.1)	
51-99	89 (15.8)	11 873 (15.6)	.16	84 (15.2)	413 (15.0)	.02
100-149	135 (23.9)	15 822 (20.9)		130 (23.6)	634 (23.0)	
150-199	91 (16.1)	13 323 (17.6)		91 (16.5)	469 (17.0)	
≥200	213 (37.7)	32 029 (42.2)		211 (38.3)	1070 (38.8)	
Hospital occupancy at time of admission, median (IQR), %	70 (60-90)	80 (70-90)	.10	70 (60-90)	80 (70-90)	.15
ICU occupancy, median (IQR)	80 (60-100)	80 (60-90)	.02	80 (60-100)	80 (60-90)	.14
ICU type[i]						
Medical ICU	158 (28.0)	15 135 (19.9)		154 (27.9)	748 (27.2)	
CCU	140 (24.8)	29 827 (39.3)		140 (25.4)	747 (27.1)	
Other ICU	63 (11.2)	4590 (6.0)	.37	61 (11.1)	288 (10.5)	.05
Other step-down	28 (5.0)	4984 (6.6)		22 (4.0)	98 (3.6)	
Cardiac step-down	19 (3.4)	2246 (3.0)		19 (3.4)	96 (3.5)	
Other	157 (27.8)	19 087 (25.2)		61 (11.1)	778 (28.2)	

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Table 1. Demographic, Clinical, and Treatment Characteristics in Unmatched and Propensity-Matched Patients With Out-of-Hospital STEMI[a] (continued)

Characteristic	Unmatched groups			Propensity-matched groups		
	Patients, No. (%)			Patients, No. (%)		
	With COVID-19 (n = 565)	Without COVID-19 (n = 75 869)	Standardized difference	With COVID-19 (n = 551)	Without COVID-19 (n = 2755)	Standardized difference
Treatment characteristics						
Coronary angiography	463 (81.9)	65 392 (86.2)	.12	451 (81.9)	2263 (82.1)	.008
PCI						
Any	451 (79.8)	62 063 (81.8)	.05	440 (79.9)	2131 (77.4)	.06
Primary[j]	401 (71.0)	56 344 (74.3)	.07	390 (70.8)	1918 (69.6)	.03
CABG	20 (3.5)	3977 (5.2)	.08	20 (3.6)	189 (6.9)	.15
Fibrinolytics only	11 (1.9)	156 (0.2)	.17	11 (2.0)	6 (0.2)	.17
Mechanical circulatory support	62 (11.0)	7681 (10.1)	.03	61 (11.1)	304 (11.0)	.001
Intra-aortic balloon pump	57 (10.1)	6817 (9.0)	.04	56 (10.2)	259 (9.4)	.03
LVAD	22 (3.9)	2462 (3.2)	.04	22 (4.0)	108 (3.9)	.004
ECMO	8 (1.4)	1252 (1.7)	.02	8 (1.5)	64 (2.3)	.06

Abbreviations: CABG, coronary artery bypass grafting; CCU, cardiac care unit; COPD, chronic obstructive pulmonary disease; ECMO, extracorporeal membrane oxygenation; ICU, intensive care unit; LVAD, left ventricular assist device; PCI, percutaneous coronary intervention.

[a] Out-of-hospital ST-segment elevation myocardial infarction (STEMI) was defined through *International Classification of Diseases, Tenth Revision* coding (see eTable 1 in the Supplement) as both present on admission and the primary diagnosis. Not all variables in the table were included in the propensity-score matching. A list of these variables is presented in the eMethods in the Supplement.

[b] Race and ethnicity were determined at the hospital level. Other indicates American Indian or Alaska Native and Native Hawaiian or Other Pacific Islander.

[c] Non–health care facility indicates physician referral of a patient from home, the workplace, or a physician's office.

[d] Law enforcement/court refers to transfers of incarcerated individuals.

[e] Other includes government-assisted health care, military, auto insurance, workers' compensation, research, Title V maternal and child health, county medically indigent service, charity, self-pay/uninsured, self-pay cash in full, other, and unknown.

[f] The database provides the Elixhauser score for every patient. The score sums the presence of 30 comorbid conditions, with higher scores reflecting greater risk of in-hospital mortality.

[g] Urban defined as core-based statistical area that encompasses at least 2500 people, at least 1500 of whom reside outside institutional group quarters.

[h] Proprietary ownership indicates for-profit institutions. Voluntary ownership indicates nonprofit institutions.

[i] Intensive care unit type provided by Vizient Clinical Database. Categories were collapsed for simplification. For more details see eMethods in the Supplement.

[j] Primary percutaneous coronary intervention indicates coronary angioplasty/stenting performed in the setting of STEMI without prior administration of fibrinolytic agents.

OR, 1.87 [95% CI, 1.22-2.85]; P = .003) (eTable 5 in the Supplement), and a control group excluding patients who were transferred (14.1% vs 10.3%; absolute difference 3.9% [95% CI, 0.3-7.5]; OR, 1.44 [95% CI, 1.06-1.96]; P = .02) (eTable 6 in the Supplement). On multivariable regression analysis after propensity matching with a control group from the previous calendar year (ie, 2019), COVID-19 remained associated with significantly higher rates of in-hospital mortality (OR, 1.60 [95% CI, 1.17-2.19]; P = .003) (eTable 7 in the Supplement).

In-Hospital STEMI

Study Population

Baseline characteristics of patients with vs without COVID-19 are summarized in Table 2. Characteristics that were not well matched are specified in the eMethods in the Supplement. Standardized mean differences for patient characteristics appear in the eMethods in the Supplement. Across 353 centers, 359 patients with COVID-19 were diagnosed with STEMI while hospitalized for other conditions, 203 (56.6%) of whom had COVID-19 as their primary diagnosis. During the same months in 2019 and 2020, a total of 3656 patients (2078 in 2019 and 1578 in 2020), in whom a COVID-19 diagnosis was not present, were diagnosed with STEMI.

Patient age was not significantly different between the groups, but, compared with those without COVID-19, patients with COVID-19 were significantly more likely to be men (71% vs 59.7%; P < .001), less likely to be White (51.8% vs 72.7%; P < .001), and more likely to be Hispanic (21.7% vs 6.8%; P < .001). The median (IQR) Elixhauser comorbidity score was not significantly different between the groups (4.0 [3.0-6.0] vs 4.0 [2.0-6.0]; P = .27). Patients with COVID-19 were significantly less likely to be admitted with heart failure (17.5% vs 28.8%; P < .001) and significantly more likely to present with cardiac arrest (26.2% vs 16.4%; P < .001) than those without COVID-19.

Treatment Characteristics

Patients with COVID-19 were significantly more likely to receive fibrinolytics as standalone therapy (8.1% vs 1.0%; P < .001), but significantly less likely to undergo coronary angiography (30.4% vs 50.8%; P < .001), any PCI (22.8% vs 36.5%; P < .001), or coronary artery bypass grafting (0.3% vs 7.3%; P < .001) compared with those without COVID-19. Mechanical circulatory support was used significantly less often in patients with COVID-19 (5.0% vs 12.1%; P < .001), a difference that was driven by greater use of intra-aortic balloon pumps and percutaneous left ventricular assist devices.

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Table 2. Demographic, Clinical, and Treatment Characteristics in Unmatched and Propensity-Matched Patients With In-Hospital STEMI[a]

Characteristic	Unmatched groups			Propensity-matched groups		
	Patients, No. (%)			Patients, No. (%)		
	With COVID-19 (n = 359)	Without COVID-19 (n = 3656)	Standardized difference	With COVID-19 (n = 252)	Without COVID-19 (n = 756)	Standardized difference
Patient demographics						
Age, y						
31-50	34 (9.5)	369 (10.1)	.11	27 (10.7)	78 (10.3)	.11
51-64	105 (29.2)	1062 (29.0)		66 (26.2)	212 (28.0)	
65-74	96 (26.7)	1075 (29.4)		72 (28.6)	203 (26.9)	
75-79	55 (15.3)	448 (12.3)		38 (15.1)	94 (12.4)	
80-84	29 (8.1)	330 (9.0)		21 (8.3)	77 (10.2)	
85-89	25 (7.0)	227 (6.2)		18 (7.1)	61 (8.1)	
≥90	15 (4.2)	145 (4.0)		10 (4.0)	31 (4.1)	
Sex						
Men	255 (71.0)	2182 (59.7)	.24	168 (66.7)	484 (64.0)	.06
Women	104 (29.0)	1474 (40.3)		84 (33.3)	272 (36.0)	
Race[b]	(n = 353)	(n = 3583)				
Asian	24 (6.8)	101 (2.8)	.48	16 (6.3)	29 (3.8)	.13
Black	74 (21.0)	578 (16.1)		51 (20.2)	138 (18.3)	
White	183 (51.8)	2606 (72.7)		159 (63.1)	502 (66.4)	
Other	72 (20.3)	298 (8.3)		26 (10.3)	87 (11.5)	
Hispanic ethnicity[b]	71 (21.7)	225 (6.8)	.44	26 (10.3)	65 (8.6)	.06
Admission source						
Non-health care facility[c]	249 (69.4)	2285 (62.5)	.35	168 (66.7)	483 (63.9)	.31
Transfer from another facility	67 (18.7)	761 (20.8)		52 (20.6)	149 (19.7)	
Transfer from skilled nursing facility or intermediate care facility	27 (7.5)	139 (3.8)		18 (7.1)	24 (3.2)	
Clinic referral	13 (3.6)	433 (11.8)		12 (4.8)	89 (11.8)	
Law enforcement/court, other transfer, or not available[d]	3 (0.8)	38 (1.0)		2 (0.8)	11 (1.5)	
Payer						
Medicare	208 (57.9)	2316 (63.3)	.13	156 (61.9)	459 (60.7)	.07
Private	73 (20.3)	715 (19.6)		46 (18.3)	154 (20.4)	
Medicaid	48 (13.4)	398 (10.9)		34 (13.5)	90 (11.9)	
Other[e]	30 (8.4)	227 (6.2)		16 (6.3)	53 (7.0)	
Cardiac comorbidities						
Hypertension	289 (80.5)	3073 (84.1)	.09	207 (82.1)	608 (80.4)	.04
Hyperlipidemia	204 (56.8)	2199 (60.1)	.07	150 (59.5)	431 (57.0)	.05
Diabetes	179 (49.9)	1583 (43.3)	.13	123 (48.8)	339 (44.8)	.08
Prior coronary artery disease	177 (49.3)	2617 (71.6)	.47	152 (60.3)	460 (60.8)	.01
Obesity	106 (29.5)	849 (23.2)	.14	66 (26.2)	183 (24.2)	.05
Cardiac arrest on admission	94 (26.2)	598 (16.4)	.24	56 (22.2)	142 (18.8)	.09
Heart failure on admission	63 (17.5)	1052 (28.8)	.27	52 (20.6)	168 (22.2)	.04
Cerebrovascular disease	58 (16.2)	786 (21.5)	.14	48 (19.0)	131 (17.3)	.05
Prior stroke	37 (10.3)	442 (12.1)	.06	30 (11.9)	81 (10.7)	.04
Prior CABG	28 (7.8)	315 (8.6)	.03	24 (9.5)	76 (10.1)	.019
Smoking	21 (5.8)	662 (18.1)	.38	21 (8.3)	62 (8.2)	.005
Valvular heart disease	20 (5.6)	502 (13.7)	.28	18 (7.1)	53 (7.0)	.005
Prior coronary intervention	6 (1.7)	64 (1.8)	.006	3 (1.2)	12 (1.6)	.03
Prior myocardial infarction	0	22 (0.6)	.11	0	6 (0.8)	.13

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Table 2. Demographic, Clinical, and Treatment Characteristics in Unmatched and Propensity-Matched Patients With In-Hospital STEMI[a] (continued)

Characteristic	Unmatched groups			Propensity-matched groups		
	Patients, No. (%)			Patients, No. (%)		
	With COVID-19 (n = 359)	Without COVID-19 (n = 3656)	Standardized difference	With COVID-19 (n = 252)	Without COVID-19 (n = 756)	Standardized difference
Other comorbidities						
Chronic anemia	188 (52.4)	2336 (63.9)	.24	148 (58.7)	448 (59.3)	.01
Coagulopathy	144 (40.1)	1143 (31.3)	.019	84 (33.3)	241 (31.9)	.03
Chronic kidney disease	119 (33.1)	1324 (36.2)	.06	92 (36.5)	264 (34.9)	.03
COPD	85 (23.7)	975 (26.7)	.07	70 (27.8)	199 (26.3)	.03
Chronic liver disease	56 (15.6)	680 (18.6)	.08	40 (15.9)	130 (17.2)	.04
Pulmonary circulation disorder	47 (13.1)	613 (16.8)	.10	35 (13.9)	112 (14.8)	.03
End-stage kidney disease	19 (5.3)	345 (9.4)	.16	17 (6.7)	53 (7.0)	.01
Elixhauser comorbidity score, median (IQR)[f]	4.0 (3.0-6.0)	4.0 (2.0-6.0)	.06	4.0 (3.0-6.0)	4.0 (3.0-6.0)	.09
Facility characteristics						
Beds						
0-150	74 (20.6)	569 (15.6)		47 (18.7)	138 (18.3)	
151-250	35 (9.7)	217 (5.9)	.21	24 (9.5)	60 (7.9)	.06
251-500	54 (15.0)	631 (17.3)		43 (17.1)	133 (17.6)	
>500	196 (54.6)	2239 (61.2)		138 (54.8)	425 (56.2)	
Urban[g]	353 (98.3)	3598 (98.4)	.007	247 (98.0)	743 (98.3)	.02
Region						
Northeast	126 (35.1)	1179 (32.2)		81 (32.1)	221 (29.2)	
Midwest	85 (23.7)	1043 (28.5)	.18	71 (28.2)	215 (28.4)	.12
Southeast	71 (19.8)	789 (21.6)		52 (20.6)	168 (22.2)	
Southwest	41 (11.4)	267 (7.3)		24 (9.5)	59 (7.8)	
West	36 (10.0)	378 (10.3)		24 (9.5)	93 (12.3)	
Ownership[h]						
Voluntary	261 (74.8)	2701 (75.7)	.04	192 (76.2)	569 (75.3)	.06
Governmental	76 (21.8)	765 (21.4)		54 (21.4)	162 (21.4)	
Proprietary	12 (3.4)	102 (2.9)		6 (2.4)	25 (3.3)	
No. of patients with STEMI treated per year, mean						
≤50	21 (5.8)	112 (3.1)		9 (3.6)	27 (3.6)	
51-99	81 (22.6)	526 (14.4)	.27	47 (18.7)	133 (17.6)	.04
100-149	74 (20.6)	800 (21.9)		56 (22.2)	162 (21.4)	
150-199	61 (17.0)	677 (18.5)		43 (17.1)	135 (17.9)	
≥200	122 (34.0)	1541 (42.1)		97 (38.5)	299 (39.6)	
Hospital occupancy at time of admission, median (IQR), %	80 (60-90)	80 (70-90)	.03	80 (60-90)	80 (70-90)	.003
ICU occupancy, median (IQR)	80 (70-120)	80 (70-100)	.39	80 (70-110)	80 (70-100)	.36
ICU type[i]						
Medical ICU	140 (39.0)	901 (24.6)		83 (32.9)	237 (31.3)	
CCU	55 (15.3)	931 (25.5)		46 (18.3)	148 (19.6)	
Other ICU	49 (13.6)	679 (18.6)	.37	39 (15.5)	129 (17.1)	.07
Other step-down	18 (5.0)	165 (4.5)		13 (5.2)	37 (4.9)	
Cardiac step-down	12 (3.3)	167 (4.6)		8 (3.2)	28 (3.7)	
Other	85 (23.7)	813 (22.2)		63 (25.0)	177 (23.4)	

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Table 2. Demographic, Clinical, and Treatment Characteristics in Unmatched and Propensity-Matched Patients With In-Hospital STEMI[a] (continued)

Characteristic	Unmatched groups			Propensity-matched groups		
	Patients, No. (%)			Patients, No. (%)		
	With COVID-19 (n = 359)	Without COVID-19 (n = 3656)	Standardized difference	With COVID-19 (n = 252)	Without COVID-19 (n = 756)	Standardized difference
Treatment characteristics						
Coronary angiography	109 (30.4)	1858 (50.8)	.43	87 (34.5)	337 (44.6)	.21
Any PCI	82 (22.8)	1335 (36.5)	.37	68 (27.0)	245 (32.4)	.12
Fibrinolytics only	29 (8.1)	38 (1.0)	.34	17 (6.7)	11 (1.5)	.27
Primary PCI[j]	4 (1.1)	334 (9.1)	.30	3 (1.2)	71 (9.4)	.37
CABG	1 (0.3)	267 (7.3)	.37	1 (0.4)	44 (5.8)	.32
Mechanical circulatory support	18 (5.0)	442 (12.1)	.26	16 (6.3)	69 (9.1)	.10
Intra-aortic balloon pump	11 (3.1)	355 (9.7)	.27	10 (4.0)	52 (6.9)	.13
LVAD	7 (1.9)	131 (3.6)	.10	6 (2.4)	21 (2.8)	.03
ECMO	2 (0.6)	139 (3.8)	.22	1 (0.4)	22 (2.9)	.19

Abbreviations: CABG, coronary artery bypass grafting; CCU, cardiac care unit; COPD, chronic obstructive pulmonary disease; ECMO, extracorporeal membrane oxygenation; ICU, intensive care unit; LVAD, left ventricular assist device; PCI, percutaneous coronary intervention; STEMI, ST elevation myocardial infarction.

[a] In-hospital ST-segment elevation myocardial infarction (STEMI) was defined through *International Classification of Diseases, Tenth Revision* coding (eTable 1 in Supplement) as nonprimary diagnosis coding and not present on admission. Not all variables in the table were included in the propensity-score matching. A list of these variables is presented in the eMethods in the Supplement.

[b] Race and ethnicity were determined at the hospital level. Other indicates American Indian or Alaska Native and Native Hawaiian or Other Pacific Islander.

[c] Non–health care facility indicates physician referral of a patient from home, the workplace, or a physician's office.

[d] Law enforcement/court refers to transfers of incarcerated individuals.

[e] Other includes government-assisted health care, military, auto insurance, workers' compensation, research, Title V maternal and child health, county medically indigent service, charity, self-pay/uninsured, self-pay cash in full, other, and unknown.

[f] The database provides the Elixhauser score for every patient. The score sums the presence of 30 comorbid conditions, with higher scores reflecting greater risk of in-hospital mortality.

[g] Urban defined as core-based statistical area that encompasses at least 2500 people, at least 1500 of whom reside outside institutional group quarters.

[h] Proprietary ownership indicates for-profit institutions. Voluntary ownership indicates nonprofit institutions.

[i] Intensive care unit type provided by Vizient Clinical Database. Categories were collapsed for simplification. For more details see eMethods in the Supplement.

[j] Primary percutaneous coronary intervention indicates coronary angioplasty/stenting performed in the setting of STEMI without prior administration of fibrinolytic agents.

Primary Outcome

The unadjusted primary outcome in patients with vs without COVID-19 and in-hospital STEMI is summarized in eTable 2 and eFigure 2 in the Supplement. The propensity-matched primary outcome is shown in Figure 2. Patients with COVID-19 vs without COVID-19 had significantly higher rates of in-hospital mortality (78.5% vs 46.1%; absolute difference, 32.4% [95% CI, 29.1%-35.9%], OR, 4.11 [95% CI, 2.97-5.69]; $P < .001$) (Figure 2).

Secondary Outcomes

Unadjusted secondary outcomes in patients with vs without COVID-19 and in-hospital STEMI are summarized in eTable 2 and eFigure 2 in the Supplement. Propensity-matched secondary outcomes are shown in Figure 2. Patients with COVID-19 had significantly higher rates of composite death, stroke, or MI (80.9% vs 50.9%; absolute difference, 29.9% [95% CI, 26.7%-33.2%]; $P < .001$) and composite death or stroke (80.9% vs 50.4%; absolute difference, 30.5% [95% CI, 27.2%-33.7%], $P < .001$); other secondary outcomes were not significantly different between the groups (Figure 2).

Exploratory Outcomes

Unadjusted and propensity-matched exploratory outcomes in patients with vs without COVID-19 and in-hospital STEMI are summarized in eTables 2 and 3 in the Supplement.

Sensitivity Analyses

In sensitivity analyses, rates of in-hospital mortality remained significantly higher in patients with COVID-19 compared with a control group from the same calendar year (ie, 2020) (79.2% vs 49.9%; absolute difference, 29.4% [95% CI, 22.5%-36.2%]; OR, 3.84 [95% CI, 2.73-5.38]; $P < .001$) (eTable 4 in the Supplement), a control group matched on center (74.0% vs 45.9%; absolute difference, 28.2% [95% CI, 18.6%-37.8%]; OR, 3.37 [95% CI, 2.16-5.24]; $P < .001$) (eTable 5 in the Supplement), and a control group excluding patients who were transferred (76.4% vs 42.2%; absolute difference, 34.2% [95% CI, 27.0%- 41.3%]; OR, 4.43 [95% CI, 3.06-6.41]; $P < .001$) (eTable 6 in the Supplement). Results from a multivariable regression analysis after propensity matching with a control group from the previous calendar year (ie, 2019) showed that COVID-19 was associated with significantly higher rates of in-hospital mortality (OR, 5.77 [95% CI, 3.93-8.46]; $P < .001$) (eTable 7 in the Supplement).

Discussion

In this retrospective cohort study, patients with out-of-hospital or in-hospital STEMI and a concomitant diagnosis of COVID-19 had a higher rate of in-hospital mortality compared

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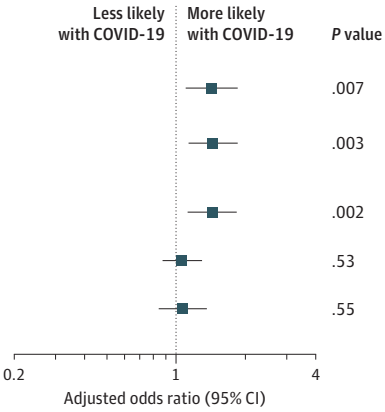
Figure 2. Association Between COVID-19 Diagnosis and Outcomes Among Propensity-Matched Patients With Out-of-Hospital and In-Hospital ST-Segment Elevation Myocardial Infarction (STEMI)

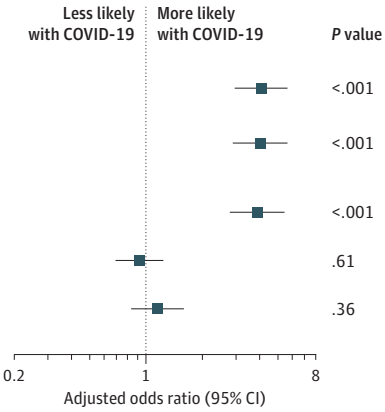
A Out-of-hospital STEMI

Outcome	Patients, No. (%) With COVID-19 (n = 551)	Patients, No. (%) Without COVID-19 (n = 2755)	Absolute difference (95% CI)	Odds ratio (95% CI) Unadjusted	Odds ratio (95% CI) Adjusted	P value
Primary						
In-hospital death	84 (15.2)	308 (11.2)	4.1 (1.09 to 7.04)	1.85 (1.48 to 2.32)	1.43 (1.1 to 1.86)	.007
Secondary						
Composite of death, stroke, or myocardial infarction	99 (18.0)	364 (13.2)	4.8 (1.58 to 7.93)	1.91 (1.55 to 2.36)	1.44 (1.13 to 1.84)	.003
Composite of death or stroke	99 (18.0)	362 (13.1)	4.8 (1.65 to 8.00)	1.88 (1.53 to 2.33)	1.45 (1.13 to 1.85)	.002
Acute decompensated heart failure	175 (31.8)	838 (30.4)	1.3 (-2.51 to 5.20)	1.07 (0.90 to 1.27)	1.06 (0.87 to 1.30)	.53
Cardiogenic shock	101 (18.3)	476 (17.3)	1.1 (-2.15 to 4.25)	1.11 (0.90 to 1.37)	1.07 (0.85 to 1.36)	.55



B In-hospital STEMI

Outcome	Patients, No. (%) With COVID-19 (n = 252)	Patients, No. (%) Without COVID-19 (n = 756)	Absolute difference (95% CI)	Odds ratio (95% CI) Unadjusted	Odds ratio (95% CI) Adjusted	P value
Primary						
In-hospital death	193 (76.6)	335 (44.3)	32.3 (25.15 to 39.40)	6.23 (4.83 to 8.04)	4.11 (2.97 to 5.69)	<.001
Secondary						
Composite of death, stroke, or myocardial infarction	199 (79.0)	369 (48.8)	30.2 (23.09 to 37.23)	5.76 (4.41 to 7.52)	3.94 (2.82 to 5.50)	<.001
Composite of death or stroke	199 (79.0)	364 (48.1)	30.8 (23.74 to 37.90)	5.66 (4.33 to 7.39)	4.04 (2.89 to 5.65)	<.001
Acute decompensated heart failure	107 (42.5)	335 (44.3)	-1.9 (-8.93 to 5.22)	0.56 (0.45 to 0.69)	0.93 (0.70 to 1.24)	.61
Cardiogenic shock	69 (27.4)	185 (24.5)	2.9 (-3.28 to 9.10)	0.94 (0.74 to 1.19)	1.16 (0.84 to 1.61)	.36



with propensity-matched groups of patients without COVID-19 admitted during the previous calendar year. Results were consistent in multiple sensitivity analyses, including an analysis using a control group of patients without COVID-19 from the same calendar year.

In previous studies, the incidence of cardiovascular events, including cardiovascular death and MI, was higher among those with influenza and influenza-like illnesses, such as SARS-CoV-1 and Middle East respiratory syndrome-related coronavirus.[16-19] Additionally, the likelihood of admission for acute MI during a 7-day risk interval after a laboratory diagnosis of influenza was increased 6-fold.[20] Differential treatment strategies and poorer in-hospital outcomes have also been observed among patients with acute MI and concomitant viral respiratory illness.[21]

Multiple studies have examined the prevalence and management of STEMI during the COVID-19 pandemic. Significant alterations in volume,[1-4] disruptions in systems of care and management protocols,[3-5] and potentially poorer outcomes compared with historical control patients have been described.[3,5] However, there are no broadly representative robust data on patients with STEMI and a concomitant COVID-19 diagnosis. In an uncontrolled, descriptive study of 78 patients with COVID-19 who presented with STEMI at 4 hospitals in Italy, Lithuania, Spain, and Iraq, a higher-than-anticipated rate of stent thrombosis was observed.[22] A single-center unadjusted analysis found higher rates of coronary stent thrombosis in patients with STEMI undergoing primary PCI when a COVID-19 diagnosis was present (n = 39) than when it was not.[7] In an unadjusted analysis from 7 heart attack centers in London, patients with a COVID-19 diagnosis (n = 46) had longer length of stay and were at greater risk of mortality after an MI compared with patients without COVID-19.[23] In the North American COVID-19 ST-Segment-Elevation Myocardial Infarction registry,[6] which included patients with STEMI or new left bundle-branch block from 64 US and Canadian centers and propensity matched those with a COVID-19 diagnosis (n = 171) to approximately 15 000 historical control patients treated at 6 Midwest PCI-capable hospitals between 2003 through prepandemic 2020,[24] adjusted

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in-hospital mortality (32% vs 6%; $P < .001$) and stroke (3.4% vs 0.6%; $P = .039$) were significantly more common among patients with vs without COVID-19. In the international COVID-acute coronary syndrome registry, 144 patients from 55 international centers who underwent invasive coronary angiography in the setting of STEMI and confirmed or suspected COVID-19 were propensity matched to 21 675 control patients enrolled in the 2018 and 2019 British Cardiovascular Intervention Society registry; in-hospital mortality was significantly higher in patients with COVID-19 on both unmatched and multivariable propensity-matched analyses (OR, 3.33 [95% CI, 2.04-5.42]).[25]

Data from patients with STEMI who were hospitalized for other illnesses are relatively limited, and current clinical trials, system initiatives, and guidelines are mainly directed toward those with out-of-hospital STEMI.[26] Few studies suggest that patients who have in-hospital STEMI are older,[26,27] are less likely to undergo PCI,[26] and have higher rates of in-hospital death[26] and 1-year death[27] compared with those with out-of-hospital STEMI.

As in other studies of COVID-19, patients with COVID-19 were younger, less likely to be White, and more likely to be Hispanic compared with those who did not have COVID-19.[28,29] Patients with COVID-19 were also more likely to present with cardiac arrest, which is consistent with increased rates of in-hospital and out-of-hospital cardiac arrest observed elsewhere during the pandemic.[30,31] In contrast, the study observations about primary treatment strategies were novel. Fibrinolytics were used as reperfusion therapy in patients with out-of-hospital STEMI more often in those with a COVID-19 diagnosis than without, but the efficacy and safety of this strategy relative to primary PCI is unknown in patients with COVID-19. PCI remained the dominant therapy in both groups, with overall rates approximating those reported in other large nationwide cohorts.[32] In contrast, among patients with in-hospital STEMI, the rates of coronary revascularization were significantly lower in those with COVID-19 than without COVID-19, although rates were quite low in both groups. Whether this change in approach resulted from a perceived futility of invasive therapy in these patients, perceived risk to health care workers, or both is unknown.

Limitations

This study has several limitations. First, as an observational study, an unknown amount of residual unmeasured confounding and bias may remain, despite propensity matching. Second, the clinical database includes primarily US academic medical centers; the findings may not be generalizable to all centers. Third, although most of the clinical characteristics and outcomes included in the study were well defined through 1 or more *ICD-10* codes, some variables did not have validation literature, and miscoding cannot be excluded. Fourth, the clinical database does not collect information on cause of death. Similarly, it does not collect data on patient symptoms, so it is not possible to ascertain whether COVID-19 diagnosis was suspected clinically or diagnosed solely based on routine testing. Nevertheless, the overlap of symptoms between STEMI and COVID-19 (eg, shortness of breath, chest pain) would make this distinction clinically challenging. Fifth, although models of in-hospital mortality after STEMI included all available demographic and comorbid characteristics, other information that has been prognostic in models[33] was not available, such as in-hospital vital signs, test results (eg, from electrocardiograms, cardiac biomarkers, and echocardiograms), time to reperfusion (eg, door-to-balloon time, door-to-needle time), and procedural detail (eg, angiographic and treatment characteristics). Likewise, scores such as the Acute Physiology and Chronic Health Evaluation II[34] and Sequential Organ Failure Assessment[35] have been applied to predict mortality in patients with COVID-19; these scores include vital signs, laboratory variables, and other measurements that were not routinely available in the database, and imbalances in these measurements may have accounted in part for the differential outcomes observed. Sixth, in contrast to the out-of-hospital STEMI group, it was not possible to discern the timing of PCI relative to the timing of the STEMI diagnosis in the in-hospital STEMI group; hence, rates of primary PCI were not presented for the latter. Seventh, this study primarily examined in-hospital outcomes. Longer-term data are needed to fully understand the effect of COVID-19 infection on patients with STEMI.

Conclusions

Among patients with out-of-hospital or in-hospital STEMI, a concomitant diagnosis of COVID-19 was associated with significantly higher rates of in-hospital mortality compared with patients without a diagnosis of COVID-19 from the past year. Further research is required to understand the potential mechanisms underlying this association.

ARTICLE INFORMATION

Accepted for Publication: October 4, 2021.

Published Online: October 29, 2021. doi:10.1001/jama.2021.18890

Author Contributions: Dr Aronow had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Saad, Louis, Aronow.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Saad, Louis, Aronow.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Saad, Kennedy, Shippey, Aronow.
Administrative, technical, or material support: Poppas, Wood, Aronow.
Supervision: Louis, Aronow.

Conflict of Interest Disclosures: Dr Poppas reported being a board member/officer of the American College of Cardiology, being a guest editor-in-chief of the *Journal of the American College of Cardiology*, receiving royalties from UpToDate as a contributor, and receiving royalties as co-editor of *Hurst's The Heart*. Dr Abbott reported receiving institutional grants from AstraZeneca and Abbott and personal fees for consulting from Boston Scientific, Philips, and Medtronic for consulting outside the submitted work. Dr Aronow reported receiving personal fees from Philips and Silk Road Medical for consulting outside the submitted work. No other disclosures were reported.

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