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Acute Cardiac Events During COVID-19-Associated Hospitalizations

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ABSTRACT

BACKGROUND COVID-19 is associated with cardiac complications.

OBJECTIVES The purpose of this study was to estimate the prevalence, risk factors, and outcomes associated with acute cardiac events during COVID-19-associated hospitalizations among adults.

METHODS During January 2021 to November 2021, medical chart abstraction was conducted on a probability sample of adults hospitalized with laboratory-confirmed SARS-CoV-2 infection identified from 99 U.S. counties in 14 U.S. states in the COVID-19-Associated Hospitalization Surveillance Network. We calculated the prevalence of acute cardiac events (identified by International Classification of Diseases-10th Revision-Clinical Modification codes) by history of underlying cardiac disease and examined associated risk factors and disease outcomes.

RESULTS Among 8,460 adults, 11.4% (95% CI: 10.1%-12.9%) experienced an acute cardiac event during a COVID-19-associated hospitalization. Prevalence was higher among adults who had underlying cardiac disease (23.4%; 95% CI: 20.7%-26.3%) compared with those who did not (6.2%; 95% CI: 5.1%-7.6%). Acute ischemic heart disease (5.5%; 95% CI: 4.5%-6.5%) and acute heart failure (5.4%; 95% CI: 4.4%-6.6%) were the most prevalent events; 0.3% (95% CI: 0.1%-0.5%) experienced acute myocarditis or pericarditis. Risk factors varied by underlying cardiac disease status. Patients with ≥1 acute cardiac event had greater risk of intensive care unit admission (adjusted risk ratio: 1.9; 95% CI: 1.8-2.1) and in-hospital death (adjusted risk ratio: 1.7; 95% CI: 1.3-2.1) compared with those who did not.

CONCLUSIONS Acute cardiac events were common during COVID-19-associated hospitalizations, particularly among patients with underlying cardiac disease, and are associated with severe disease outcomes. Persons at greater risk for experiencing acute cardiac events during COVID-19-associated hospitalizations might benefit from more intensive clinical evaluation and monitoring during hospitalization. (J Am Coll Cardiol 2023;81:557-569) Published by Elsevier on behalf of the American College of Cardiology Foundation.

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ABBREVIATIONS AND ACRONYMS

BNP = B-type natriuretic peptide

ECMO = extracorporeal membrane oxygenation

ICD-10-CM = International Classification of Diseases-10th Revision-Clinical Modification

ICU = Intensive care unit

NT-proBNP = N-terminal prohormone B-type natriuretic peptide

As of September 2022, >96 million SARS-CoV-2 infections have been confirmed in the United States,[1] and COVID-19 is a leading cause of death.[2] Underlying cardiac diseases, including heart failure, coronary artery disease, and cardiomyopathies, are established risk factors for COVID-19 severity.[3,4]

Although acute COVID-19 requiring hospitalization typically manifests as acute respiratory illness,[5] extrapulmonary complications can include myocardial injury, arrhythmias, heart failure, cardiogenic shock, myocarditis, and ischemia.[6-17] Increased risk for cardiac complications can persist up to 1 year after patients have recovered from acute COVID-19.[18] Additionally, patients who experience acute cardiac events in the context of acute COVID-19 might be at increased risk for severe disease outcomes, including intensive care unit (ICU) admission, invasive mechanical ventilation, or death during hospitalization.[7,8]

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A comprehensive assessment of acute cardiac events among a large and geographically diverse sample of patients hospitalized with SARS-CoV-2 infection and their associated risk factors and severe disease outcomes can inform clinical and public health practice. The objective of this investigation was to describe the prevalence, risk factors, and severity of acute cardiac events among adults during COVID-19-associated hospitalizations from January 2021 to November 2021, overall and by underlying cardiac disease status.

METHODS

PARTICIPANTS AND PROCEDURES. This secondary analysis used data from the COVID-NET (Coronavirus Disease-2019 Hospitalization Surveillance Network), a population-based surveillance system that identifies hospitalized patients with laboratory-confirmed SARS-CoV-2 infection within a network of >250 acute care hospitals.[19-21] COVID-NET conducts surveillance in a 99-county catchment area in 14 states (California, Colorado, Connecticut, Georgia, Iowa, Maryland, Michigan, Minnesota, New Mexico, New York, Ohio, Oregon, Tennessee, and Utah) that includes approximately 10% of the U.S. population. COVID-NET defines COVID-19-associated hospitalizations as hospitalizations for any acute medical reason of patients who live in the surveillance catchment area and have SARS-CoV-2 detected by molecular or antigen test within 14 days before or during their hospitalization. Cases are identified from notifiable disease and laboratory databases and from hospital admission and infection control practitioner logs. This activity was determined by the U.S. Centers for Disease Control and Prevention to be nonresearch public health surveillance and was conducted consistent with applicable federal law and U.S. Centers for Disease Control and Prevention policy (45 C.F.R. part 46, 21 C.F.R. part 56; 42 U.S.C. Sect. 241(d); 5 U.S.C. Sect. 552a; and 44 U.S.C. Sect. 3501 et seq). COVID-NET sites obtained approval from their respective state and local Institutional Review Boards, as required.

The study period for this investigation was January 2021 to November 2021, when COVID-19 vaccinations were authorized for emergency use by the U.S. Food and Drug Administration. Trained surveillance officers abstracted detailed demographic and clinical information from the medical records of a representative sample of COVID-NET cases aged ≥18 years and reported them to COVID-NET on a monthly basis using a standardized case report form. The representative sample was selected on a monthly basis from random numbers assigned to each case; the probability of selection varied by surveillance month, COVID-NET site, and age group. Abstracted information includes demographic and clinical characteristics, in-hospital clinical interventions and outcomes, and up to 9 International Classification of Diseases-10th Revision-Clinical Modification (ICD-10-CM) codes at discharge. Surveillance officers also collect information on the sampled patients' COVID-19 vaccination status (vaccination product received, number of doses, and administration dates) from state Immunization Information Systems in all sites except Iowa.[22]

For this analysis, data from sampled cases were weighted to account for the probability of selection

The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

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and adjusted for nonresponse because of incomplete medical chart abstraction at the time the data were processed. The weights were additionally adjusted (ie, raked and trimmed) to align the weighted case distribution by surveillance month, COVID-NET site, and age group, with the population totals in the catchment area to minimize overdispersion.[23]

Of 127,919 adults aged ≥18 years hospitalized with laboratory-confirmed SARS-CoV-2 infection during January 2021 to November 2021, a probability sample of 11,267 (8.8%) was selected for medical chart abstraction (Supplemental Figure 1). Hospitalizations were excluded for any of the following nonmutually exclusive reasons: ICD-10-CM codes were not available (n = 2,304; 20.5%), the patient was pregnant at admission (n = 645; 5.7%), chart abstraction was incomplete (n = 308; 2.7%), or the patient had not been discharged at the time data were analyzed (n = 182; 1.6%). We did not exclude patients who were not primarily admitted for COVID-19-related illness (n = 657; 6.5%), because myocardial injury has been documented among patients with mild or moderate COVID-19.[24] In total, 8,460 (75.1%) cases were included in this analysis. Included patients were significantly older and were more likely to be men relative to sampled patients who were excluded (Supplemental Table 1).

MEASURES. Acute cardiac events. Patients were classified as having ≥1 acute cardiac event during a COVID-19-associated hospitalization if they had any of 68 billable ICD-10-CM codes for new primary or secondary cardiac diagnoses at discharge (Supplemental Table 2). Additionally, patients were classified as having an acute cardiac event if they had acute myocardial infarction, acute myocarditis, or congestive heart failure listed as new diagnoses, exacerbations of pre-existing diagnoses, or new episodes of pre-existing diagnoses in the summary list of discharge diagnoses or accompanying narrative. To differentiate between acute events vs chronic conditions, we limited ICD-10-CM codes to those with the terms *acute, acute-on-chronic,* or *exacerbation* or those that are inherently acute events.[25] Some diagnoses (eg, atrial fibrillation, other cardiac arrhythmias) were excluded from this analysis because we could not confidently differentiate acute from chronic events. Acute cardiac events were further classified into the following 5 nonmutually exclusive categories: acute heart failure, acute myocarditis or pericarditis, hypertensive crisis, ischemic heart disease, or other heart diseases (Supplemental Table 2).

Underlying medical conditions. History of select underlying medical conditions was determined based on review of the patient's admission history and physical, emergency department report, consultation notes, and discharge summary. Information on the following 8 categories of underlying medical conditions was collected for each case: cardiac disease, chronic kidney disease, chronic obstructive pulmonary disease, diabetes mellitus, diseases of the circulatory system, hypertension, obstructive sleep apnea, or severe obesity (calculated body mass index ≥40 kg/m^2 or ICD-10-CM codes for severe obesity) (Supplemental Table 3). Patients were classified as having underlying cardiac disease if they had a history of atrial fibrillation, coronary artery disease, congestive heart failure, cardiac pacemaker in situ, pulmonary hypertension, or valvular disease. For all categories of underlying medical conditions, the Referent group includes no or unknown history of the condition.

Demographic characteristics. Demographic variables included age in years, sex, and race or Hispanic ethnicity group (Hispanic, non-Hispanic Black, non-Hispanic White, non-Hispanic Asian or Pacific Islander, or non-Hispanic other). Patients with unknown ethnicity (n = 578; 7.3%) were classified as non-Hispanic.

Clinical characteristics. Based on review of the patient's chief complaint and history of present illness, the primary reason for admission for each hospitalization was classified as likely COVID-19-related illness or other (ie, inpatient surgery or procedure, psychiatric admission needing acute medical care, trauma, other, or unknown with no symptoms consistent with COVID-19 illness).[26] Patients were classified as having completed their primary COVID-19 vaccine series if they had completed the second dose of a 2-dose series by any manufacturer or after 1 dose of a single-dose series by any manufacturer ≥14 days before their positive SARS-CoV-2 test. Patients were further classified as having completed their primary COVID-19 vaccine series and boosted if they received an additional or booster dose ≥14 days before their positive SARS-CoV-2 test.[27] The Referent group includes both unvaccinated adults and partially vaccinated adults (ie, those who had not completed a primary COVID-19 vaccine series by any manufacturer ≥14 days before their positive SARS-CoV-2 test). Information on history of tobacco use (current, former, or never/unknown) and select initial signs and symptoms and vital signs at admission were also collected.

Laboratory values. For patients hospitalized during January 2021 to September 2021, initial serum concentrations of troponin, B-type natriuretic peptide (BNP) and N-terminal prohormone B-type natriuretic peptide (NT-proBNP) were abstracted. COVID-NET does not systematically collect laboratory data for all cases; these data are only abstracted if ordered by a provider within 24 hours of admission. Collection of these variables was discontinued after September 2021. Reported values of troponin-I, -T, or -type not specified were combined into a single variable, and values reported in ng/L or pg/mL were converted to ng/mL. Initial values for BNP or NT-proBNP reported in ng/L or ng/mL respectively were converted to pg/mL.

Severe disease outcomes. In-hospital interventions and outcomes included ICU admission, length of hospital and ICU stay in days, receipt of invasive mechanical ventilation or extracorporeal membrane oxygenation (ECMO), and in-hospital death from any cause.

STATISTICAL ANALYSIS. Using survey procedures in SAS version 9.4 (SAS Institute), we calculated the unadjusted, weighted prevalence and 95% CI of experiencing ≥1 acute cardiac event overall and among patients with and without underlying cardiac disease. We present distributions of demographic characteristics and underlying medical conditions, clinical characteristics, and in-hospital interventions among patients by whether they had an acute cardiac event during their COVID-19-associated hospitalization or not. Descriptive information about the minimum, maximum, median, IQR, and 90th percentiles for initial troponin, BNP, or NT-proBNP values ordered within 24 hours of admission are only reported for adults who experienced ≥1 acute cardiac event during hospitalization because of missing data among patients who did not experience an acute cardiac event while hospitalized. We did not categorize these values, because COVID-NET does not collect information on assay type, and the upper reference limits are therefore unavailable. Counts are unweighted values, but all other measures are weighted to reflect the probability of selection. Additionally, jackknife replicate weights are used to estimate variance, accounting for the complex sampling design.

To identify risk factors for experiencing acute cardiac events during hospitalization, we specified bivariate and multivariable log-linked Poisson generalized estimating equations using robust variance estimators to account for clustering of hospitalizations within the 14 COVID-NET sites. Bivariate models include age group and surveillance month in addition to the independent variable of interest to account for the complex sampling design. Multivariable models were adjusted for the following covariates: age group, surveillance month, sex, race and ethnicity group, tobacco use history, vaccination status, and history of underlying medical conditions. Because pathophysiology can vary by category of acute cardiac event, we modeled risk factors for acute ischemic heart disease and acute heart failure as separate dependent variables. We present unadjusted RRs and adjusted risk ratios (aRRs), 95% CIs, and *P* values using a type I error rate of 5%. We used a similar modeling approach to estimate the association between experiencing ≥1 acute cardiac event and severe disease outcomes, using ICU admission, invasive mechanical ventilation or ECMO, and in-hospital death as dependent variables. *P* values and CIs were not adjusted for multiplicity; inferences drawn from these statistics may not be reproducible.

RESULTS

PREVALENCE OF ACUTE CARDIAC EVENTS. The prevalence of experiencing ≥1 acute cardiac event among adults overall during a COVID-19-associated hospitalization was 11.4% (95% CI: 10.1%-12.9%) and was significantly higher among adults with a history of underlying cardiac disease (23.4%; 95% CI: 20.7%-26.3%) compared with those without underlying cardiac disease (6.2%; 95% CI: 5.1%-7.6%) (Table 1). Acute ischemic heart disease (5.5%; 95% CI: 4.5%-6.5%) and acute heart failure (5.4%; 95% CI: 4.4%-6.6%) were the most prevalent categories of acute cardiac events; both categories were significantly more common among adults with underlying cardiac disease relative to those without underlying cardiac disease. The most frequent ICD-10-CM codes in the acute ischemic heart disease category were for type 2 myocardial infarction (2.1%), non-ST-segment elevation myocardial infarction (1.3%), and other forms of acute ischemic heart disease (1.2%); 1.8% of patients had a discharge diagnosis of acute myocardial infarction (Supplemental Table 2). The most frequent ICD-10-CM codes in the acute heart failure category were for acute-on-chronic diastolic (1.4%) or systolic (1.3%) heart failure; 3.4% had a discharge diagnosis of congestive heart failure. Hypertensive crisis (1.0%; 95% CI: 0.7%-1.4%), acute myocarditis or pericarditis (0.3%; 95% CI: 0.1%-0.5%), and other acute cardiac events (1.1%; 95% CI: 0.7%-1.8%) occurred less commonly.

DEMOGRAPHIC CHARACTERISTICS OF PATIENTS BY ACUTE CARDIAC DISEASE STATUS. Adults who experienced ≥1 acute cardiac event while hospitalized with laboratory-confirmed SARS-CoV-2 infection during January 2021 to November 2021 had a median age of 69 years (IQR: 56-80 years) and 56.5% were men (Table 2). The largest race and ethnicity group was non-Hispanic White (48.7%), followed by non-Hispanic Black (33.6%), Hispanic (7.4%), and non-Hispanic Asian or Pacific Islander (7.1%). Approximately 12.8% were current smokers. The most common underlying medical conditions were hypertension (78.2%), underlying cardiac disease (61.9%), obesity (48.9%), diabetes mellitus (45.0%), and chronic kidney disease (30.0%). The most common underlying cardiac diseases were congestive heart failure (44.0%), coronary artery disease (28.4%), and atrial fibrillation (23.5%). The majority (72.8%) had not completed their primary COVID-19 vaccine series at the time of admission. Approximately 25.8% had completed their primary series at admission, and 9.9% had received an additional or booster dose. The majority (96.8%) were primarily admitted for COVID-19-related illness. In bivariate analyses, patients who were older; were men; were of Hispanic ethnicity; were current or former smokers; or had hypertension, obesity, diabetes mellitus, cardiac disease, chronic kidney disease, diseases of the circulatory system, obstructive sleep apnea, or chronic obstructive pulmonary disease were significantly more likely to experience ≥1 acute cardiac event. Demographic characteristics of patients by category of acute cardiac event are reported in Supplemental Table 4.

RISK FACTORS FOR ACUTE ISCHEMIC HEART DISEASE. In multivariable analyses, the risk of experiencing acute ischemic heart disease during a COVID-19-associated hospitalization was significantly greater among patients in older age groups (age 50-64 years vs 18-49 years: aRR: 1.4; 95% CI: 1.1-1.9; age ≥65 years vs 18-49 years: aRR: 1.8; 95% CI: 1.3-2.5); men (aRR: 1.3; 95% CI: 1.0-1.6); and those with a history of chronic kidney disease (aRR: 1.4; 95% CI: 1.1-1.8), valve disease (aRR: 1.6; 95% CI: 1.2-2.0), or hypertension (aRR: 1.5; 95% CI: 1.1-2.0) (Table 3).

Risk factors varied by whether the patient had a history of known underlying cardiac disease. Among patients without documented underlying cardiac disease, hypertension (aRR: 1.8; 95% CI: 1.4-2.3) was associated with significantly increased risk of experiencing acute ischemic heart disease. Among patients with underlying cardiac disease, older age (age ≥65 vs 18-49 years: aRR: 1.9; 95% CI: 1.0-3.6), male sex (aRR: 1.4; 95% CI: 1.2-1.8), and history of valve disease (aRR: 1.4; 95% CI: 1.2-1.8) were associated with greater risk of acute ischemic heart disease.

TABLE 1 Prevalence of Acute Cardiac Events Among Adults Aged ≥18 Years Hospitalized With Laboratory-Confirmed SARS-CoV-2 Infection

	All Patients (N = 8,460)	No Underlying Cardiac Disease[a] (n = 6,093, 69.9%)	≥1 Underlying Cardiac Disease[a] (n = 2,367, 30.1%)
≥1 acute cardiac event	11.4 (10.1-12.9)	6.2 (5.1-7.6)	23.4 (20.7-26.3)
Acute ischemic heart disease	5.5 (4.5-6.5)	3.8 (3.0-4.7)	9.4 (7.1-12.1)
Acute heart failure	5.4 (4.4-6.6)	1.6 (1.0-2.2)	14.4 (11.8-17.4)
Hypertensive crisis	1.0 (0.7-1.4)	0.9 (0.6-1.3)	1.3 (0.6-2.3)
Acute myocarditis or pericarditis	0.3 (0.1-0.5)	0.2 (0.1-0.4)	0.4 (0.1-1.1)
Other acute cardiac event	1.1 (0.7-1.8)	0.7 (0.3-1.4)	2.1 (1.4-3.0)

Values are prevalence (95% CI). No corrections for multiple testing were applied. [a]Cardiac disease includes congestive heart failure, coronary artery disease, atrial fibrillation, valve disease, pacemaker, or pulmonary hypertension.

RISK FACTORS FOR ACUTE HEART FAILURE. In multivariable analyses, the risk of experiencing acute heart failure during a COVID-19-associated hospitalization was significantly greater among men (aRR: 1.5; 95% CI: 1.1-2.0) and among those with a history of congestive heart failure (aRR: 13.5; 95% CI: 10.7-17.0), atrial fibrillation (aRR: 1.6; 95% CI: 1.4-1.9), or hypertension (aRR: 1.3; 95% CI: 1.1-1.6). History of coronary artery disease was associated with significantly lower risk of acute heart failure during a COVID-19-associated hospitalization (aRR: 0.7; 95% CI: 0.6-0.9) (Table 4).

Risk factors varied by whether the patient had a history of known underlying cardiac disease. Among patients without underlying cardiac disease, older age (age ≥65 years vs 18-49 years: aRR: 2.7; 95% CI: 1.8-4.0), male sex (aRR: 2.8; 95% CI: 1.7-4.8), and history of hypertension (aRR: 1.6; 95% CI: 1.2-2.2) were associated with significantly greater risk of experiencing acute heart failure. Among patients with underlying cardiac disease, history of congestive heart failure (aRR: 9.4; 95% CI: 6.3-14.0) or atrial fibrillation (aRR: 1.7; 95% CI: 1.4-2.1) were associated with significantly greater risk of experiencing acute heart failure; history of coronary artery disease was associated with significantly lower risk of experiencing acute heart failure (aRR: 0.7; 95% CI: 0.6-0.9) (Table 4).

CLINICAL PRESENTATION AT ADMISSION. Signs, symptoms, and initial vital signs at admission are reported in Supplemental Table 5. Among patients with acute ischemic heart disease with available data (88.8%), medium initial serum troponin concentration was 0.11 ng/mL (IQR: 0.05-0.42 ng/mL). Among patients with acute heart failure with available data

TABLE 2 Characteristics of Adults Hospitalized With SARS-CoV-2 Infection by Acute Cardiac Event Status

	All Patients (N = 8,460)	≥1 Acute Cardiac Event (n = 920)	No Acute Cardiac Event (n = 7,540)	*P* Value[a]
Age, y	61 (48-73)	69 (56-80)	60 (47-72)	—
Age group, y				
18-49[b]	2,503 (27.4)	133 (14.3)	2,370 (29.1)	Ref
50-64	2,957 (30.6)	310 (26.0)	2,647 (31.2)	<0.0001
≥65	3,000 (42.0)	477 (60.0)	2,523 (39.7)	<0.0001
65-74	1,401 (19.9)	194 (25.2)	1,207 (19.3)	—
75-84	1,014 (13.3)	163 (19.5)	851 (12.5)	—
85+	585 (8.8)	120 (15.0)	465 (8.0)	—
Sex				
Female	4,070 (48.3)	400 (43.5)	3,670 (48.9)	Ref
Male	4,390 (51.7)	520 (56.5)	3,870 (51.1)	0.02
Race and ethnicity group				
White, NH	4,610 (48.7)	505 (48.7)	4,105 (48.7)	Ref
Black, NH	1,904 (28.4)	256 (33.6)	1,648 (27.7)	0.93
AAPI, NH	363 (5.9)	51 (7.1)	312 (5.8)	0.77
Hispanic or Latino	1,160 (12.0)	80 (7.4)	1,080 (12.6)	<0.0001
Other, NH[c]	423 (5.0)	28 (3.1)	395 (5.2)	0.23
Underlying conditions[d]				
Hypertension	4,615 (58.0)	691 (78.2)	3,924 (55.4)	<0.0001
Obesity[e]	4,313 (49.7)	463 (48.9)	3,850 (49.8)	0.01
Severe obesity	1,355 (15.8)	172 (18.3)	1,183 (15.5)	<0.0001
Diabetes mellitus	2,676 (33.6)	397 (45.0)	2,279 (32.1)	<0.0001
Cardiac disease	2,367 (30.1)	547 (61.9)	1,820 (26.0)	<0.0001
Coronary artery disease	1,307 (16.1)	279 (28.4)	1,028 (14.6)	<0.0001
Congestive heart failure	990 (13.1)	375 (44.0)	615 (9.1)	<0.0001
Atrial fibrillation	782 (9.8)	206 (23.5)	576 (8.0)	<0.0001
Valve disease	516 (6.2)	109 (12.5)	407 (5.3)	<0.0001
Pacemaker	217 (3.1)	65 (7.9)	152 (2.5)	<0.0001
Pulmonary hypertension	104 (1.8)	36 (5.8)	68 (1.2)	<0.0001
Chronic kidney disease	1,229 (16.1)	270 (30.0)	959 (14.4)	<0.0001
Diseases of the circulatory system	1,161 (14.3)	189 (20.7)	972 (13.5)	<0.0001
Cerebrovascular disease	529 (6.6)	84 (7.9)	445 (6.4)	<0.0001
Pulmonary embolism/deep vein thrombosis	562 (6.6)	85 (10.5)	477 (6.1)	<0.0001
Peripheral artery or vascular disease	208 (2.7)	46 (4.2)	162 (2.6)	<0.0001
Obstructive sleep apnea	1,012 (10.9)	161 (14.3)	851 (10.5)	<0.0001
Chronic obstructive pulmonary disease	871 (10.6)	165 (18.2)	706 (9.7)	<0.0001
Tobacco use				
No/unknown	5,329 (64.1)	502 (58.5)	4,827 (64.8)	Ref
Former	2,093 (24.1)	287 (28.6)	1,806 (23.5)	<0.0001
Current	1,038 (11.9)	131 (12.8)	907 (11.7)	<0.0001
COVID-19 vaccination status[f]				
Not completed primary series	6,422 (78.5)	625 (72.8)	5,797 (79.3)	Ref
Completed primary series	1,819 (18.7)	279 (25.8)	1,540 (17.8)	<0.0001
Received additional dose or booster dose	657 (7.0)	82 (9.9)	575 (6.6)	—
Vaccination status unavailable	219 (2.8)	16 (1.4)	203 (3.0)	—
Primary reason for admission				
COVID-19-related	7,803 (93.5)	881 (96.8)	6,922 (93.1)	0.66
Not likely COVID-19-related	657 (6.5)	39 (3.2)	618 (6.9)	Ref

Values are median (IQR) or n (%). Counts are unweighted and percentages are weighted. No corrections for multiple testing were applied. [a]*P* values are derived from multivariable generalized estimating equation models that include age group and surveillance month and account for clustering by COVID-NET site. [b]253 (2.7%) of patients were aged 18-25 years. [c]Includes American Indian or Alaska Native, non-Hispanic/Latino (NH) (132; 1.3%); multiple races, NH (35; 0.5%), or unknown (256; 3.2%). [d]For each medical condition, no or unknown history of the condition was used as the Reference group. [e]Obesity was defined as having calculated body mass index ≥30 kg/m^2 or International Classification of Diseases-10th Revision-Clinical Modification codes for obesity. Severe obesity was defined as calculated body mass index ≥40 kg/m^2 or International Classification of Diseases-10th Revision-Clinical Modification codes for severe obesity. [f]Patients were classified as having completed their primary COVID-19 vaccine series if they had completed the second dose of a 2-dose series or after 1 dose of a single-dose series ≥14 days before their positive SARS-CoV-2 status. Patients were further classified as having completed their primary COVID-19 vaccine series and boosted if they received an additional or booster dose ≥14 days before hospitalization.

AAPI = Asian American or Pacific Islander.

TABLE 3 Prevalence and Risk Factors for Acute Ischemic Heart Disease Among COVID-19-Associated Hospitalizations

			Multivariable Models[a]								
	Prevalence (N = 8,241)		All Patients (N = 8,241)[b]			Patients With No Underlying Cardiac Disease (n = 5,939)[b]			Patients With ≥1 Underlying Cardiac Disease (n = 2,302)[b]		
	PR	(95% CI)	aRR	(95% CI)	*P* Value	aRR	(95% CI)	*P* Value	aRR	(95% CI)	*P* Value
Age group, y											
18-49	2.9	(2.1-3.9)	Ref			Ref			Ref		
50-64	5.1	(3.8-6.6)	1.4	(1.1-1.9)	0.009	1.2	(1.0-1.6)	0.10	1.5	(0.8-2.7)	0.18
≥65	7.8	(5.9-10.0)	1.8	(1.3-2.5)	0.0005	1.4	(1.0-2.2)	0.09	1.9	(1.0-3.6)	0.04
Sex											
Female	4.8	(3.8-6.0)	Ref			Ref			Ref		
Male	6.3	(4.9-8.0)	1.3	(1.0-1.6)	0.02	1.1	(0.9-1.5)	0.33	1.4	(1.2-1.8)	0.0004
Race/ethnicity group											
White, NH	5.8	(4.7-7.0)	Ref			Ref			Ref		
Black, NH	5.8	(3.8-8.5)	1.3	(1.0-1.6)	0.07	1.4	(0.8-2.3)	0.24	1.1	(0.7-1.7)	0.64
Hispanic/Latino	3.1	(2.1-4.6)	0.7	(0.5-1.1)	0.10	0.8	(0.5-1.4)	0.40	0.6	(0.4-1.0)	0.05
Other, NH[c]	6.8	(4.1-10.6)	1.3	(0.7-2.1)	0.39	1.3	(0.7-2.3)	0.45	1.2	(0.7-2.2)	0.47
Underlying medical conditions											
Chronic kidney disease	10.0	(6.7-14.2)	1.4	(1.1-1.8)	0.02	1.4	(0.9-2.0)	0.14	1.4	(1.0-1.9)	0.07
Any cardiac disease	9.6	(7.3-12.3)	—	—	—	—	—	—	—	—	—
Pulmonary hypertension	13.6	(5.2-27.1)	1.4	(0.7-2.7)	0.32	—	—	—	1.4	(0.7-2.8)	0.29
Congestive heart failure	11.5	(7.5-16.7)	1.6	(1.0-2.6)	0.06	—	—	—	1.5	(1.0-2.4)	0.08
Valve disease	11.4	(6.7-17.7)	1.6	(1.2-2.0)	0.0002	—	—	—	1.4	(1.2-1.8)	0.001
Pacemaker	10.6	(4.2-21.0)	0.9	(0.6-1.4)	0.64	—	—	—	0.9	(0.6-1.5)	0.78
Atrial fibrillation	10.1	(6.4-14.8)	1.2	(0.9-1.4)	0.18	—	—	—	1.0	(0.8-1.2)	0.86
Coronary artery disease	9.8	(7.9-11.9)	1.2	(0.9-1.7)	0.23	—	—	—	1.1	(0.8-1.6)	0.55
Chronic obstructive pulmonary disease	8.1	(5.5-11.5)	1.0	(0.7-1.4)	0.87	1.4	(0.9-2.3)	0.13	0.8	(0.5-1.1)	0.17
Hypertension	7.2	(6.0-8.6)	1.5	(1.1-2.0)	0.02	1.8	(1.4-2.3)	<0.0001	1.0	(0.6-1.7)	0.93
Diabetes mellitus (type 1 or 2)	6.5	(5.1-8.1)	1.0	(0.7-1.2)	0.68	1.0	(0.8-1.3)	0.94	0.9	(0.5-1.5)	0.67
Diseases of the circulatory system	5.9	(3.3-9.5)	0.7	(0.4-1.1)	0.09	0.5	(0.2-1.0)	0.04	0.7	(0.4-1.2)	0.18
Obstructive sleep apnea	5.9	(4.1-8.2)	0.8	(0.6-1.1)	0.13	0.8	(0.3-1.9	0.62	0.7	(0.5-1.1)	0.11
Obesity[d]	5.3	(3.9-7.0)	—	—	—	—	—	—	—	—	—
Severe obesity	5.2	(3.4-7.5)	1.1	(0.8-1.4)	0.72	0.8	(0.6-1.1)	0.14	1.3	(0.9-1.8)	0.11
Tobacco use											
None	5.0	(4.2-6.0)	Ref			Ref			Ref		
Former	6.5	(4.6-8.8)	1.0	(0.7-1.3)	0.83	1.3	(0.9-1.8)	0.20	0.7	(0.5-1.2)	0.24
Current	6.9	(4.6-9.9)	1.3	(0.9-1.8)	0.16	1.2	(0.5-2.7)	0.72	1.2	(0.9-1.7)	0.22
COVID-19 vaccination status at admission[b]											
Not completed primary series	5.2	(4.2-6.4)	Ref			Ref			Ref		
Completed primary series	8.5	(6.1-11.5)	1.1	(0.8-1.3)	0.66	1.2	(0.8-1.9)	0.32	0.9	(0.7-1.2)	0.36

No corrections for multiple testing were applied. [a]Multivariable generalized estimating equations include surveillance month as a covariate and account for clustering of hospitalizations within COVID-NET sites. [b]Models exclude patients whose vaccination status could not be determined caused by unavailable data. Patients were classified as having completed their primary COVID-19 vaccinate series if they had completed the second dose of a 2-dose series or after 1 dose of a single-dose series ≥14 days before their positive SARS-CoV-2 status; all other patients were classified as having not completed their primary COVID-19 vaccine series. [c]Includes Asian American or Pacific islander, non-Hispanic/Latino (NH); American Indian or Alaska Native, NH; multiple races, NH, and unknown. [d]Obesity was defined as having calculated body mass index ≥30 kg/m^2 or International Classification of Diseases-10th Revision-Clinical Modification codes for obesity. Severe obesity was defined as calculated body mass index ≥40 kg/m^2 or International Classification of Diseases-10th Revision-Clinical Modification codes for severe obesity.

aRR = adjusted risk ratio; PR = prevalence.

(45.1% for BNP, 28.9% for NT-proBNP), median initial serum concentration was 438 pg/mL (IQR: 154-1,071 pg/mL) for BNP and 2,448 pg/mL (IQR: 483-12,181 pg/mL) for NT-proBNP (Table 5).

SEVERE DISEASE OUTCOMES BY ACUTE CARDIAC EVENT. Among patients who experienced ≥1 acute cardiac event, 39.2% (95% CI: 32.9%-45.8%) required ICU admission for a median of 5 days (IQR: 2-11 days) (Table 6). Approximately 22.4% (95% CI: 19.5%-25.6%) required invasive mechanical ventilation or ECMO, and 21.1% (95% CI: 17.9%-24.7%) died during hospitalization. The prevalence of ICU admission and in-hospital death were highest among patients who experienced acute ischemic heart disease, acute heart failure, or other acute cardiac events and lowest among patients who experienced hypertensive crisis or acute myocarditis or pericarditis (Table 6).

TABLE 4 Prevalence and Risk Factors for Acute Heart Failure Among COVID-19-Associated Hospitalizations

	Prevalence (N = 8,241)		Multivariable Models[a]								
			All Patients (N = 8,241)[b]			Patients With No Underlying Cardiac Disease (n = 5,939)[b]			Patients With ≥1 Underlying Cardiac Disease (n = 2,302)[b]		
	PR	(95% CI)	aRR	(95% CI)	*P* Value	aRR	(95% CI)	*P* Value	aRR	(95% CI)	*P* Value
Age group, y											
18-49	2.5	(1.6-3.7)	Ref			Ref			Ref		
50-64	4.0	(2.9-5.5)	1.1	(0.7-1.8)	0.73	0.9	(0.5-1.6)	0.75	0.9	(0.5-1.7)	0.83
≥65	8.5	(6.2-11.3)	1.5	(0.8-2.9)	0.25	2.7	(1.8-4.0)	<0.0001	1.0	(0.5-2.1)	0.99
Sex											
Female	4.5	(3.5-5.8)	Ref			Ref			Ref		
Male	6.4	(4.7-8.3)	1.5	(1.1-2.0)	0.006	2.8	(1.7-4.8)	0.0001	1.3	(1.0-1.7)	0.07
Race and ethnicity group											
White, NH	5.5	(4.5-6.6)	Ref			Ref			Ref		
Black, NH	6.2	(4.9-7.8)	1.1	(0.8-1.5)	0.54	0.6	(0.2-2.0)	0.43	1.2	(1.0-1.4)	0.07
Hispanic or Latino	3.8	(1.5-7.8)	1.2	(0.7-2.0)	0.59	1.0	(0.2-4.9)	0.99	1.3	(0.7-2.5)	0.46
Other, NH[c]	5.5	(1.9-12.4)	1.1	(0.7-1.7)	0.73	1.3	(0.8-2.3)	0.33	1.1	(0.6-1.8)	0.87
Underlying medical conditions											
Any cardiac disease	14.6	(11.9-17.7)	–	–	–	–	–	–	–	–	–
Congestive heart failure	29.8	(24.9-35.1)	13.5	(10.7-17.0)	<0.0001	–	–	–	9.4	(6.3-14.0)	<0.0001
Pulmonary hypertension	24.7	(9.8-46.0)	1.3	(0.7-2.5)	0.46	–	–	–	1.3	(0.7-2.3)	0.46
Atrial fibrillation	19.2	(14.2-25.1)	1.6	(1.4-1.9)	<0.0001	–	–	–	1.7	(1.4-2.1)	<0.0001
Pacemaker	15.5	(10.4-21.9)	0.7	(0.3-1.7)	0.44	–	–	–	0.7	(0.3-1.7)	0.42
Valve disease	11.8	(7.8-16.7)	1.0	(0.8-1.3)	0.77	–	–	–	1.0	(0.8-1.2)	0.98
Coronary artery disease	10.2	(8.1-12.7)	0.7	(0.6-0.9)	0.005	–	–	–	0.7	(0.6-0.9)	0.003
Chronic kidney disease	12.8	(8.9-17.6)	0.9	(0.6-1.3)	0.61	0.8	(0.4-1.4)	0.35	1.0	(0.6-1.5)	0.90
Chronic obstructive pulmonary disease	10.9	(8.3-13.9)	0.9	(0.6-1.5)	0.77	0.8	(0.2-2.7)	0.66	0.9	(0.6-1.4)	0.77
Diseases of the circulatory system	10.2	(7.8-13.0)	1.1	(0.8-1.4)	0.53	1.7	(0.9-3.5)	0.12	1.0	(0.8-1.2)	0.91
Obstructive sleep apnea	8.9	(6.8-11.5)	0.9	(0.7-1.2)	0.41	0.7	(0.4-1.2)	0.20	0.9	(0.7-1.1)	0.36
Diabetes mellitus (type 1 or 2)	8.1	(6.2-10.3)	1.1	(1.0-1.2)	0.05	1.3	(0.7-2.4)	0.46	1.2	(1.0-1.4)	0.11
Hypertension	7.6	(6.2-9.2)	1.3	(1.1-1.6)	0.01	1.6	(1.2-2.2)	0.004	1.0	(0.8-1.3)	0.93
Obesity[d]	5.2	(4.3-6.2)	–	–	–	–	–	–	–	–	–
Severe obesity	7.5	(5.5-9.9)	1.3	(1.0-1.7)	0.05	1.4	(0.9-2.4)	0.16	1.2	(1.0-1.4)	0.10
Smoking status											
None	4.6	(3.2-6.4)	Ref			Ref			Ref		
Former	7.2	(5.2-9.7)	0.9	(0.7-1.2)	0.52	0.7	(0.3-1.6)	0.40	1.0	(0.7-1.3)	0.85
Current	7.0	(5.3-8.9)	1.3	(1.0-1.6)	0.08	1.3	(0.7-2.4)	0.38	1.1	(1.0-1.4)	0.17
COVID-19 vaccination status[b]											
Not completed primary series	5.3	(4.1-6.7)	Ref			Ref			Ref		
Completed primary series	7.0	(5.5-8.8)	0.9	(0.8-1.1)	0.29	0.9	(0.5-1.7)	0.40	0.9	(0.7-1.1)	0.14

No corrections for multiple testing were applied. [a]Multivariable generalized estimating equations include surveillance month as a covariate and account for clustering of hospitalizations within COVID-NET sites. [b]Models exclude patients whose vaccination status could not be determined because of unavailable data. Patients were classified as having completed their primary COVID-19 vaccine series if they had completed the second dose of a 2-dose series or after 1 dose of a single-dose series ≥14 days before their positive SARS-CoV-2 status; all other patients were classified as having not completed their primary COVID-19 vaccine series. [c]Includes Asian American or Pacific islander, NH; American Indian or Alaska Native, NH; multiple races, NH, and unknown. [d]Obesity was defined as having calculated body mass index ≥30 kg/m^2 or International Classification of Diseases-10th Revision-Clinical Modification codes for obesity. Severe obesity was defined as calculated body mass index ≥40 kg/m^{2}or International Classification of Diseases-10th Revision-Clinical Modification codes for severe obesity.

Abbreviations as in Table 3.

In multivariable models, patients who experienced ≥1 acute cardiac event had greater risk of ICU admission (aRR: 1.9; 95% CI: 1.8-2.1; $P < 0.0001$), invasive mechanical ventilation or ECMO (aRR: 2.0; 95% CI: 1.7-2.4; $P < 0.0001$), and in-hospital death (aRR: 1.7; 95% CI: 1.3-2.1; $P < 0.0001$) relative to those who did not experience an acute cardiac event during hospitalization (Table 7). Experiencing an acute cardiac event was associated with greater risk of severe disease outcomes among patients with underlying cardiac disease (ICU admission: aRR: 1.6; 95% CI: 1.3-1.8; invasive mechanical ventilation or ECMO: aRR: 1.4; 95% CI: 1.1-1.8; in-hospital death: aRR: 1.7; 95% CI: 1.3-2.1), as well as those without documented underlying cardiac disease (ICU admission: aRR: 2.5; 95% CI: 2.2-3.0; invasive mechanical

TABLE 5 Initial Laboratory Values by Acute Cardiac Event Category Among COVID-19-Associated Hospitalizations

	Acute Ischemic Heart Disease (n = 389)	Acute Heart Failure (n = 365)	Hypertensive Crisis (n = 71)	Myocarditis or Pericarditis (n = 22)	Other Acute Heart Disease (n = 101)
Troponin (ng/mL)[a]					
n (%)[b]	344 (88.8)	302 (84.9)	53 (72.2)	18 (90.5)	80 (85.4)
Minimum	0.00	0.00	0.00	0.00	0.00
Median	0.11	0.05	0.03	0.13	0.04
IQR	0.05-0.42	0.03-0.14	0.01-0.10	0.07-1.07	0.01-0.24
90th percentile	2.1	0.32	0.13	1.27	0.51
Maximum	6,242	2,640	6,242	2.6	91.6
B-type natriuretic peptide (pg/mL)[c]					
n (%)[b]	141 (34.5)	163 (45.1)	19 (27.5)	6 (13.9)	32 (26.3)
Minimum	5.0	10	14	52	5.0
Median	151	438	174	1,211	237
IQR	65.6-422	154-1,071	129-277	129-8,272	77.5-1,039
90th percentile	1,510	1,958	5,000	8,272	1,452
Maximum	6,265	70,000	5,274	8,272	24,129
N-terminal prohormone B-type natriuretic peptide (pg/mL)[c]					
n (%)[b]	70 (21.5)	114 (28.9)	11 (13.7)	3 (19.3)	30 (41.7)
Minimum	2.0	2.0	55	50	3.5
Median	933	2,448	1,549	2,223	3,610
IQR	141-9,984	483-12,181	418-2,223	2,223-2,223	714-12,533
90th percentile	27,169	23,801	175,000	2,223	14,213
Maximum	133,733	175,000	175,000	2,223	25,500

No corrections for multiple testing were applied. [a]Includes troponin-I, -t, and -unspecified. Values reported in ng/L or pg/mL were converted to ng/mL. [b]Unweighted n and weighted percent. [c]Values reported in ng/L, ng/mL, or other were converted to pg/mL.

ventilation or ECMO: aRR: 2.9; 95% CI: 2.3-3.7; in-hospital death: aRR: 2.8; 95% CI: 2.1-3.7).

DISCUSSION

More than 11% of adults experienced ≥1 acute cardiac event during a COVID-19-associated hospitalization. Acute cardiac events—most frequently acute ischemic heart disease and acute heart failure—were observed in more than 5% of those without documented underlying cardiac disease and nearly one-quarter of those with underlying cardiac disease. Adults who experienced an acute cardiac event were nearly twice as likely to require ICU admission, receive invasive mechanical ventilation or ECMO, or die during hospitalization compared with those who did not experience an acute cardiac event, regardless of history of underlying cardiac disease (Central Illustration). Although this study cannot causally attribute severe in-hospital disease

TABLE 6 Clinical Interventions and Outcomes by Acute Cardiac Event Category Among COIVD-19-Associated Hospitalizations

	n	Length of Hospitalization (d), Median (IQR)	ICU Admission, PR (95% CI)	Length of ICU Stay (d), Median (IQR)	Invasive Mechanical Ventilation or ECMO, PR (95% CI)	In-Hospital Death, PR (95% CI)
≥1 acute cardiac event	920	7 (4-13)	39.2 (32.9-45.8)	5 (2-11)	22.4 (19.5-25.6)	21.1 (17.9-24.7)
Acute ischemic heart disease	457	7 (4-13)	41.0 (34.5-47.6)	5 (2-12)	24.4 (19.9-29.4)	23.7 (19.8-28.0)
Acute heart failure	410	9 (4-16)	39.0 (30.1-48.5)	5 (1-10)	21.4 (16.2-27.3)	19.2 (13.7-25.9)
Hypertensive crisis	82	4 (2-9)	25.9 (16.8-36.7)	7 (1-11)	10.0 (2.8-28.6)	6.7 (1.1-19.8)
Myocarditis or pericarditis	25	10 (3-15)	38.0 (12.0-70.4)	3 (1-4)	5.1 (0.3-21.9)	2.4 (.008-17.9)
Other acute cardiac event	112	8 (4-17)	55.0 (42.4-67.1)	4 (2-12)	33.8 (21.5-48.1)	28.9 (20.0-39.3)
No acute cardiac event	7,540	5 (3-9)	18.6 (17.4-19.9)	7 (3-13)	10.4 (9.3-11.6)	8.6 (7.8-9.4)

No corrections for multiple testing were applied.
ECMO = extracorporeal membrane oxygenation; ICU = intensive care unit; PR = prevalence.

TABLE 7 Associations Between Acute Cardiac Event and In-Hospital Clinical Interventions Among COVID-19-Associated Hospitalizations

	Multivariable Models[a]								
	ICU Admission			Invasive Mechanical Ventilation or ECMO			In-Hospital Death		
	aRR	(95% CI)	*P* Value	aRR	(95% CI)	*P* Value	aRR	(95% CI)	*P* Value
ICU admission									
No acute cardiac event	Ref			Ref			Ref		
≥1 Acute cardiac event	1.9	(1.8-2.1)	<0.0001	2.0	(1.7-2.4)	<0.0001	1.7	(1.3-2.1)	<0.0001
Acute ischemic heart disease	1.9	(1.6-2.3)	<0.0001	2.1	(1.7-2.6)	<0.0001	1.8	(1.4-2.4)	<0.0001
Acute heart failure	1.8	(1.6-2.0)	<0.0001	1.7	(1.4-2.1)	<0.0001	1.3	(1.0-1.7)	0.02
Other acute cardiac event	2.5	(2.1-3.1)	<0.0001	2.9	(2.3-3.7)	<0.0001	2.1	(1.2-3.4)	0.005

No corrections for multiple testing were applied. [a]Multivariable generalized estimating equations include surveillance month as a covariate and account for clustering of hospitalizations within COVID-NET sites. All models are adjusted for age group, sex, race and ethnicity group, primary reason for admission, smoking status, vaccination status, surveillance month, and the following underlying medical conditions: hypertension, diabetes mellitus, chronic kidney disease, diseases of the circulatory system, chronic obstructive pulmonary disease and obstructive sleep apnea, and morbid obesity. Models exclude patients whose vaccination status could not be determined.

aRR = adjusted risk ratio; ECMO = extracorporeal membrane oxygenation; ICU = intensive care unit.

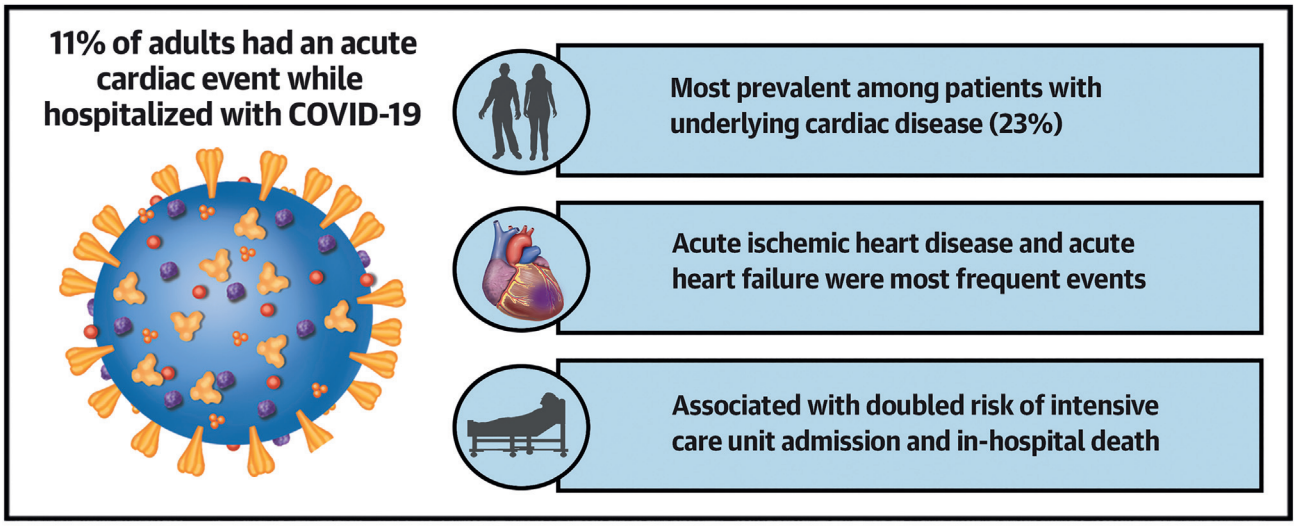
outcomes to acute cardiac events, these results highlight the morbidity and mortality associated of such events in the context of COVID-19.

Results from this investigation extend previous reports documenting acute cardiac complication among adults hospitalized with COVID-19 by providing a detailed and comprehensive assessment by category of event. Direct comparisons with findings from prior studies assessing acute myocardial infarction,[12,28] acute heart failure,[13] and myocarditis or pericarditis in the context of acute COVID-19 are limited by differences in study time periods, samples, and methodology.[14,15] However, it is important to note that the prevalence estimates of acute cardiac events, acute ischemic heart disease, acute heart failure, and hypertensive crisis in this study are within 1 percentage point of those documented by a previous study of adults hospitalized with laboratory-confirmed influenza during 2010 to 2018 upon which the methodology of this study was based.[25] Proposed mechanisms for COVID-19-associated acute cardiac events include cytokine storms, microthrombi or macrothrombi, direct viral invasion, and oxygen supply-demand imbalance, particularly among those with underlying ischemic heart disease.[8]

A novel contribution of this study was documenting the association between several underlying medical conditions and acute cardiac events by history of underlying cardiac disease. Among adults without documented underlying cardiac disease, history of hypertension was associated with increased risk of de novo acute ischemic heart disease and acute heart failure while hospitalized with COVID-19. Among adults with documented pre-existing cardiac disease, history of valve disease was associated with increased risk of acute ischemic heart disease and history congestive heart failure or atrial fibrillation with increased risk of acute heart failure during a COVID-19-associated hospitalization. The unexpected finding of lower adjusted risk of acute heart failure among patients with a history of pre-existing coronary artery disease might be explained by earlier care-seeking behavior or closer monitoring of this patient population during a COVID-19-associated hospitalization.

Acute cardiac events were associated with increased risk of severe disease outcomes among all patients, regardless of documented underlying cardiac disease. Among patients who experienced an acute cardiac event during a COVID-19-associated hospitalization, almost 40% required ICU admission and more than 20% died during hospitalization, which represented a nearly 2-fold greater adjusted risk of severe disease outcomes relative to patients who did not experience an acute cardiac event. We cannot attribute these severe disease outcomes to the acute cardiac event; the association between acute cardiac events and ICU admission indicates the severity of these events or precautionary admissions of high-risk patients for more intensive monitoring who subsequently experience an acute cardiac event. However, similar associations have been documented in previous studies. For example, in a study of more than 8,000 patients hospitalized with COVID-19 during January-July 2020 at 88 centers participating in the American Heart Association's COVID-19 Cardiovascular Disease Registry, among patients with left ventricular ejection fraction, patients with heart failure with reduced ejection fraction had significantly greater risk of in-hospital mortality.[16] Additionally, in a single-center study of patients admitted with COVID-19 in New York during the initial months of the pandemic, those who had myocardial injury indicated by elevated serum troponin-I

CENTRAL ILLUSTRATION **Acute Cardiac Events Among Adults Hospitalized With Laboratory-Confirmed SARS-CoV-2 Infection**



Woodruff RC, et al. J Am Coll Cardiol. 2023;81(6):557–569.

Results are among a probability sample of 8,460 adults with laboratory-confirmed SARS-CoV-2 infection who were hospitalized during January 2021 to November 2021 and identified by the COVID-19-Associated Hospitalizations Surveillance Network.

concentrations had 3 times the risk of in-hospital death relative to those who did not.[8]

These findings have implications for clinical and public health practice. Clinicians should be aware that acute cardiac events are common extrapulmonary complications of COVID-19 illness, including among patients without documented underlying cardiac disease. Clinicians should consider conducting a thorough history and physical evaluation among adults hospitalized with laboratory-confirmed SARS-CoV-2 infection and monitoring them for evidence of cardiac complications, including cardiac arrhythmias and cardiogenic shock, throughout their hospitalization.[17] Additionally, all patients and especially those with underlying cardiac disease, should receive recommended outpatient and inpatient COVID-19 treatments expected to have the highest net clinical benefit based on a thorough assessment with their clinicians of the potential benefits, risks, and side effects of any intervention.[29] These strategies, in combination with other evidence-based approaches to prevent or mitigate COVID-19 could reduce morbidity and mortality from associated cardiac complications. For example, clinicians can emphasize that patients with underlying cardiac disease seek testing and care early if they become ill with symptoms consistent with COVID-19, as these patients might be eligible for treatments to prevent mild or moderate illness from progressing to severe illness if detected early.[29] Adults can engage in evidence-based strategies to prevent SARS-CoV-2 infection or reduce their risk of severe COVID-19, including receiving COVID-19 vaccination and booster doses as recommended,[30] adhering to current recommendations for community mitigation measures,[31] and treating underlying cardiac disease or other medical conditions associated with increased risk of severe COVID-19.[29,30]

STUDY LIMITATIONS. First, case ascertainment likely varied during the study period, given geographic and temporal variability in SARS-CoV-2 testing capacity and performance by site. Additionally, included

patients were more likely than excluded patients to be older and be men, indicating potential selection bias. Patients with underlying cardiac disease are at greater risk for severe COVID-19[3,4]; they could have had a lower threshold for admission and potentially been admitted with milder illness relative to those without underlying cardiac disease. This investigation is also subject to misclassification bias. Patients' acute cardiac event status could have been misclassified because resource constraints limit COVID-NET to abstracting up to 9 ICD-10-CM codes per hospitalization (which are not necessarily ordered by priority and may omit cardiac event-related codes). Additionally, the sensitivity and specificity for identifying acute cardiac events based on ICD-10-CM codes is unknown, the diagnostic criteria used by participating hospitals could have varied, and information to clinically validate acute cardiac events (eg, echocardiography, cardiovascular cardiac magnetic resonance, histology, serial troponin concentrations, and laboratory values for patients admitted after September 2021) is not collected by COVID-NET. Similarly, patients' underlying medical conditions could have been misclassified if their medical history was not accurately captured in their inpatient medical record, they had underlying medical conditions not assessed as part of this investigation, or if they had underlying conditions that COVID-NET does not collect (eg, hyperlipidemia). A causal relationship between acute cardiac events and severe disease outcomes cannot be assumed, given that the temporality of these events is unknown (eg, acute cardiac events might be more likely to be detected among critically ill patients admitted caused by more intensive monitoring). COVID-NET does not collect sufficient data needed to differentiate between patients primarily admitted for an acute cardiac event vs those primarily admitted for COVID-19 who go on to experience cardiac complications. Finally, these results are from the COVID-NET catchment area, which includes approximately 10% of the population, and during a time of alpha and delta SARS-CoV-2 variant predominance; findings do not necessarily generalize to all geographic areas and time periods.

CONCLUSIONS

More than 11% of adults experienced ≥1 acute cardiac event while hospitalized with laboratory-confirmed SARS-CoV-2 infection. These events were most common among patients with underlying cardiac disease and were associated with greater risk of severe disease outcomes and in-hospital death among all patients, including those without documented underlying cardiac disease. Collectively, these results suggest that cardiac events are common extrapulmonary complications of COVID-19 and underscore the importance of rigorous clinical evaluation and monitoring of all patients hospitalized with COVID-19, especially among those with underlying cardiac disease.

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PERSPECTIVES

COMPETENCY IN PATIENT CARE AND PROCEDURAL SKILLS: Acute cardiac events occur in 11% of adults hospitalized with COVID-19, most often in patients with underlying cardiac disease, and are associated with almost double the risk of ICU admission and mortality.

TRANSLATIONAL OUTLOOK: Further research is needed to identify patients hospitalized with COVID-19 who are at risk of acute cardiac events and to develop strategies that improve their survival.

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APPENDIX For a supplemental figure and tables, please see the online version of this paper.