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In COVID-19 Patients Who Suffer In-Hospital Cardiac Arrest, Cardiopulmonary Resuscitation Outcomes May Be Impacted by Arrest Etiology and Local Pandemic Conditions

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OBJECTIVES: The utility and risks to providers of performing cardiopulmonary resuscitation after in-hospital cardiac arrest in COVID-19 patients have been questioned. Additionally, there are discrepancies in reported COVID-19 in-hospital cardiac arrest survival rates. We describe outcomes after cardiopulmonary resuscitation for in-hospital cardiac arrest in two COVID-19 patient cohorts.

DESIGN: Retrospective cohort study.

SETTING: New York-Presbyterian Hospital/Columbia University Irving Medical Center in New York, NY.

PATIENTS: Those admitted with COVID-19 between March 1, 2020, and May 31, 2020, as well as between March 1, 2021, and May 31, 2021, who received resuscitation after in-hospital cardiac arrest.

INTERVENTIONS: None.

MEASUREMENT AND MAIN RESULTS: Among 103 patients with coronavirus disease 2019 who were resuscitated after in-hospital cardiac arrest in spring 2020, most self-identified as Hispanic/Latino or African American, 35 (34.0%) had return of spontaneous circulation for at least 20 minutes, and 15 (14.6%) survived to 30 days post-arrest. Compared with nonsurvivors, 30-day survivors experienced in-hospital cardiac arrest later (day 22 vs day 7; $p = 0.008$) and were more likely to have had an acute respiratory event preceding in-hospital cardiac arrest (93.3% vs 27.3%; $p < 0.001$). Among 30-day survivors, 11 (73.3%) survived to hospital discharge, at which point 8 (72.7%) had Cerebral Performance Category scores of 1 or 2. Among 26 COVID-19 patients resuscitated after in-hospital cardiac arrest in spring 2021, 15 (57.7%) had return of spontaneous circulation for at least 20 minutes, 3 (11.5%) survived to 30 days post in-hospital cardiac arrest, and 2 (7.7%) survived to hospital discharge, both with Cerebral Performance Category scores of 2 or less. Those who survived to 30 days post in-hospital cardiac arrest were younger (46.3 vs 67.8; $p = 0.03$), but otherwise there were no significant differences between groups.

CONCLUSIONS: Patients with COVID-19 who received cardiopulmonary resuscitation after in-hospital cardiac arrest had low survival rates. Our findings additionally show return of spontaneous circulation rates in these patients may be impacted by hospital strain and that patients with in-hospital cardiac arrest preceded by acute respiratory events might be more likely to survive to 30 days, suggesting Advanced Cardiac Life Support efforts may be more successful in this subpopulation.

KEY WORDS: advanced cardiac life support; cardiopulmonary resuscitation; coronavirus disease 2019; heart arrest; retrospective studies; return of spontaneous circulation

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Since its emergence, COVID-19, the novel infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has infected more than 242 million individuals in 192 countries, resulting in greater than 4.9 million deaths (1). In New York City, an epicenter of the COVID-19 pandemic in the spring of 2020, hospitals faced a surge of critically ill patients and crisis conditions (2). Within the landscape of high reported mortality rates, significant resource scarcity, fear of infection, and lack of personal protective equipment (PPE), providers grappled during goals-of-care discussions with addressing the appropriateness of performing cardiopulmonary resuscitation (CPR) in patients with COVID-19 who suffered in-hospital cardiac arrest (IHCA) (3).

Responses to this gap in knowledge have varied, with some hospitals at times considering universal do-not-resuscitate (DNR) policies (4). Such suggestions were based on poor outcomes reported early in the pandemic (5–9), including reported survival after IHCA ranging between 0% and 12% (10–17). This differs significantly from data pertaining to non-COVID hospitalized patients, in whom survival to discharge is 26.4% according to the American Heart Association's (AHA) Get With The Guidelines Registry (GWTGR) (18).

In light of these discrepancies in reported IHCA survival rates as well as the fact that the global COVID-19 pandemic has not relented, we sought to examine IHCA in COVID-19 patients in greater detail at our medical center at multiple pandemic timepoints. We also aimed to describe the outcomes after CPR for IHCA with regards to patient demographics, comorbidities, and arrest etiologies in an effort to better inform clinical decisions and COVID-19 hospital policies (19).

MATERIALS AND METHODS

Study Design and Participants

This retrospective cohort study of hospitalized patients was conducted at New York-Presbyterian Hospital/Columbia University Irving Medical Center (CUIMC) in New York, NY. CUIMC is comprised of two hospitals in northern Manhattan which are part of the New York-Presbyterian academic healthcare system. Milstein Hospital is a 700-bed quaternary referral center, while Allen Hospital is a 230-bed community-based facility. Patients who were positive for SARS-CoV-2 via real-time reverse-transcription polymerase chain reaction testing of nasopharyngeal swab samples that were admitted to CUIMC between either March 1, 2020, and May 31, 2020, or March 1, 2021, and May 31, 2021, were identified. Eligible patients were positive for SARS-CoV-2, 18 years old or older and experienced IHCA for which they received CPR. Patients who suffered cardiac arrest in the field or in the emergency department (ED) and died before admission were excluded. For those who received CPR for multiple IHCAs, only the first was considered in our analyses. Study approval was obtained from the CUIMC Institutional Review Board (approved protocol number AAAT0698), with a waiver of informed consent provided.

As per hospital procedure, CPR in the ICU or ED was performed by in-unit resuscitative teams. Patients who suffered IHCA on the general hospital wards were resuscitated by a mobile resuscitation team available 24 hours a day, 7 days a week. Emergent intubations were performed by an in-house anesthesiologist-staffed team.

Mobile resuscitative teams typically consisted of a "code leader" physician, a nurse, respiratory therapist, and sometimes mid-level practitioners administering chest compressions. Resuscitative teams adhered to AHA guidelines for Advanced Cardiac Life Support (ACLS). Institution-specific cardiac arrest guidelines for patients with COVID-19 infection incorporated guidance on the number of providers in the room to minimize exposure risks and PPE requirements. Resuscitative efforts consisted of chest compressions, intubation, administration of medications, and/or defibrillation, the choice of and duration of which were at the code leader's discretion.

Data Collection

Patients were identified using the NewYork-Presbyterian/CUIMC Clinical Data Warehouse (CDW), a repository of clinical information for CUIMC patients. All those identified by CDW had to be confirmed eligible by one of the authors via manual chart review (C.G.M., M.S.N., S.T.C., W.A.B., M.P.) before their inclusion. Age, gender, self-identified race/

ethnicity, and body mass index (BMI) were obtained through CDW extracts of electronic health record (EHR) data. Other patient characteristics including comorbidities, advance directives, arrest location, hospital/mechanical ventilation day at time of IHCA, presence/absence of shockable rhythm, and specific organ dysfunctions preceding arrest were obtained via manual chart review. Further details are provided in the **Online Supplement** (http://links.lww.com/CCX/A878).

Definitions and Outcomes

Cardiac arrest was defined as the confirmed absence of a palpable pulse, indicating the cessation of circulation. Based upon a manual review of EHR notes and data, each IHCA was categorized by suspected etiology. Specific categories identified include acute respiratory events, acute cardiovascular events, refractory shock, hypoxemia refractory to mechanical ventilation, hypoxemia refractory to high- and/or low-flow supplemental oxygen therapies, mixed, and unknown. An acute respiratory event was considered to be the etiology if IHCA was preceded by one of the following: pneumothorax, recent intubation/extubation, endotracheal tube obstruction, aspiration, refractory patient-ventilator dyssynchrony, ventilator/tubing malfunction, oxygen mask disconnection, or venovenous extracorporeal membrane oxygenator failure. Further details pertaining to other etiology definitions are available in the supplement.

The primary outcome was survival at 30 days after IHCA. Secondary outcomes included return of spontaneous circulation (ROSC, defined as surviving for at least 20 min after arrest), survival to discharge, and neurologic status at discharge as assessed by Cerebral Performance Category (CPC) score. This 5-point assessment, which evaluates cognitive and functional domains, is the post-arrest neurologic outcome measure recommended by the Utstein Guidelines (20). CPC scores were assigned via author chart review of EHR notes.

Statistical Analysis

The "car," "tableone," "epitools," and "ggplot2" packages of R software (Version 4.0.2; R Foundation, Vienna, Austria) were used for statistical analysis. Data are expressed as frequencies and percentages for categorical variables. Continuous variables are expressed as either mean (SD) or median (interquartile range) and compared using the *t* test or Wilcoxon rank-sum, respectively, depending on normality, which was tested via the Shapiro-Wilk test. Categorical variables were compared using chi-square or Fisher exact test depending on size (> 5). Risk ratios were calculated for fields of interest. A *p* value of less than 0.05 was deemed significant for all analyses.

RESULTS

Spring 2020 Cohort

In this study period, when hospital capacity was severely strained (2), there were 2,628 eligible patients admitted to CUIMC with COVID-19 (**Fig. 1**). Of these, 642 (24.4%) suffered IHCA, of which 103 (16.0%) received ACLS. As for the remaining patients, 530 (82.6%) did not receive ACLS, and in 9 (1.4%), due to missing data, it was not possible to determine whether CPR was provided. Of the 530 patients who did not receive ACLS, 517 (97.5%) had DNR orders preceding IHCA and the remaining 13 received only pharmacologic resuscitation.

Of the 103 patients who received CPR, 68.9% of patients were male, 49.5% identified as Hispanic/Latino, and 15.5% identified as Black but not Hispanic/Latino (**Table 1**). The median BMI was 29.2 kg/m^2. The most common comorbidities were hypertension (67.0%), diabetes mellitus (46.6%), and coronary artery disease (27.2%). Those who survived IHCA to 30 days were younger than nonsurvivors (56.4 vs 68.2 yr; $p = 0.002$). There were no other significant differences in baseline characteristics between those who did and did not survive to 30 days post-IHCA.

Sixty-six of 103 patients in this cohort (64.1%) received CPR in an ICU, which included "surge ICUs" that were converted operating rooms and hospital wards after demand for ICU beds tripled (2, 21). Arrest location had no statistical impact on survival after IHCA: the risk ratio of surviving to 30 days in standard ICUs compared with all other arrest locations (binary comparison) was 1.59 (CI, 0.63–4.06; $p < 0.343$), while it was 1.26 (CI, 0.44–3.60; $p < 0.657$) in surge ICUs, and 0.47 (CI, 0.14–1.54; $p < 0.202$) in non-ICU wards compared with all other locations.

Among patients in this 2020 cohort, the most common initial rhythm was pulseless electrical activity (46.6%), followed by asystole (34.0%; **Table 2**). Fewer

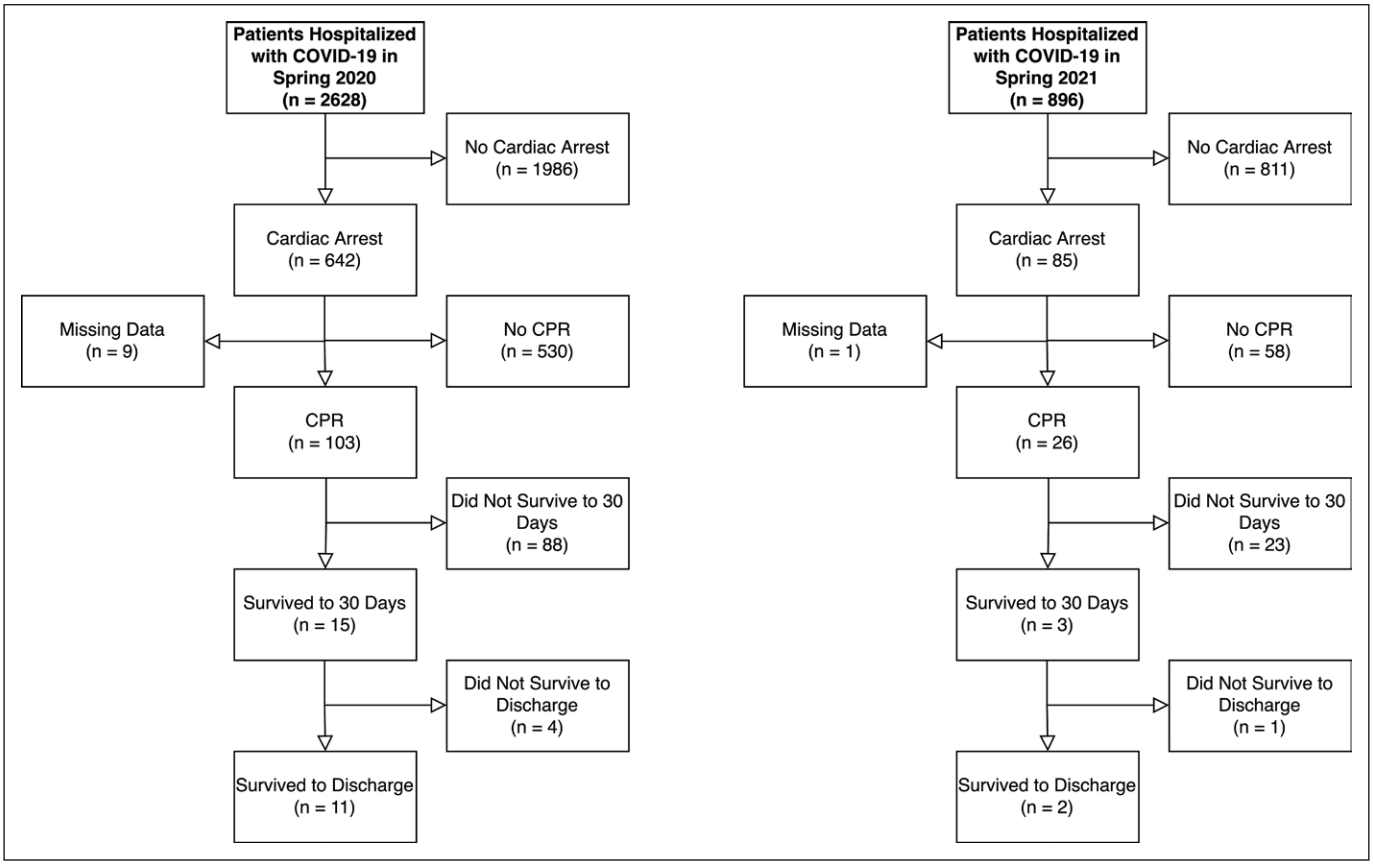

Figure 1. Study flow diagram. Electronic health record documentation for 10 patients with in-hospital cardiac arrest (IHCA) was insufficient to determine whether or not they received Advanced Cardiac Life Support resuscitation, so they were excluded from further analysis. "30 Days" refers to time elapsed after IHCA. CPR = cardiopulmonary resuscitation.

than 10% of patients had an initial shockable rhythm. IHCA occurred later in 30-day survivors' hospitalizations (median hospital day 22 vs 7; $p = 0.008$), and more patients who survived to 30 days were mechanically ventilated at the time of their arrest (93.3% vs 64.8%; $p = 0.03$). At the time of IHCA, slightly more than half of these patients were receiving vasopressor therapy (55.3%), and 34.0% were receiving renal replacement therapy.

An acute respiratory event preceded IHCA in 93.3% of 30-day survivors but only in 27.3% of those who did not survive to 30 days ($p < 0.001$) in this 2020 cohort. The most common etiology for an acute respiratory event was intubation minutes preceding the arrest followed by mucus plug obstructing the endotracheal tube (34.0% and 25.0%, respectively; **Supplement Table 1**, http://links.lww.com/CCX/A878). In 30-day nonsurvivors, the next most common IHCA etiology was refractory shock (17.0%). Those with acute respiratory events were 24 times as likely to survive to 30 days compared with those with any other etiology (binary comparison) in this cohort (risk ratio, 23.95; CI, 3.28–174.99; $p < 0.001$). While patients with acute respiratory events were more likely to survive to 30 days compared with those with other IHCA etiologies, only 36.8% of such patients did. Only one of 65 patients with a nonacute respiratory event etiology survived 30 days, and none survived to discharge.

Patients with acute respiratory events in the 2020 cohort typically had intact cardiac function. When compared with those with other etiologies, these patients were less likely to have congestive heart failure (CHF) at baseline (10.5% vs 27.7%; $p = 0.048$) and were 11% as likely to have left ventricular (LV) dysfunction (as determined by an ejection fraction of ≤ 40% on transthoracic echocardiogram during the index hospitalization) prior to IHCA (risk ratio, 0.11; CI, 0.015–0.770; $p = 0.004$). The majority of patients (70.6%) with LV dysfunction had CHF diagnoses preceding their admission. There were no other significant differences in baseline characteristics between patients suffering acute respiratory events versus other etiologies in this

TABLE 1.
Baseline Characteristics of Patients Who Underwent Advanced Cardiac Life Support Resuscitation for In-Hospital Cardiac Arrest in 2020 Cohort

Variable	All (*n* = 103)	30-d Nonsurvivors (*n* = 88)	30-d Survivors (*n* = 15)	*p*[a]
Age, mean (SD)	66.5 (13.6)	68.2 (12.9)	56.4 (14.0)	0.002
Male gender, *n* (%)	71 (68.9)	59 (67.0)	12 (80.0)	0.381
Race/ethnicity, *n* (%)[b]				0.413
Asian	1 (1.0)	1 (1.1)	0 (0.0)	
Black	16 (15.5)	12 (13.6)	4 (26.7)	
Hispanic/Latino	51 (49.5)	43 (48.9)	8 (53.3)	
Other	9 (8.7)	8 (9.1)	1 (6.7)	
Unknown	15 (14.6)	15 (17.0)	0 (0.0)	
White	11 (10.7)	9 (10.2)	2 (13.3)	
Body mass index, median (interquartile range)[c]	29.2 (25.8–33.5)	29.0 (25.5–33.5)	29.9 (27.3–33.9)	0.476
Hospitalization month, *n* (%)				0.816
March	44 (42.7)	37 (42.0)	7 (46.7)	
April	58 (56.3)	50 (56.8)	8 (53.3)	
May	1 (1.0)	1 (1.1)	0 (0.0)	
Coronary artery disease, *n* (%)[d]	28 (27.2)	24 (27.3)	4 (26.7)	1
Congestive heart failure, *n* (%)[d]	22 (21.4)	20 (22.7)	2 (13.3)	0.516
Diabetes, *n* (%)[d]	48 (46.6)	42 (47.7)	6 (40.0)	0.784
Hypertension, *n* (%)[d]	69 (67.0)	60 (68.2)	9 (60.0)	0.745
Chronic kidney disease, *n* (%)[d]	21 (20.4)	20 (22.7)	1 (6.7)	0.295
Pulmonary disease, *n* (%)[d]	18 (17.5)	16 (18.2)	2 (13.3)	1
Active malignancy, *n* (%)[d]	10 (9.7)	10 (11.4)	0 (0.0)	0.351

[a]For continuous variables, *p* values were derived from either the *t* test or Wilcoxon rank-sum test, while χ^2 or Fisher exact testing was used for categorical variables.

[b]Data on race and ethnic group, as reported by the patient, were obtained from the clinical data warehouse.

[c]The body mass index is the weight in kilograms divided by the square of the height in meters. Due to missing data, it could not be calculated in one patient who did not survive to 30 d.

[d]Comorbidity data were gathered from physician history and physical notes at the time of hospital admission prior to in-hospital cardiac arrest. Chronic kidney disease referred to stages III through V. Pulmonary disease included chronic obstructive pulmonary disease, asthma, obstructive sleep apnea, interstitial lung disease, and bronchiectasis.

cohort (**Supplement Tables 2** and **3**, http://links.lww.com/CCX/A878).

Of the 103 patients who received ACLS in the spring 2020 cohort, 35 (34.0%) had ROSC, and 15 (14.6%) were alive at 30 days (**Table 3**). Using the GWTGR across-hospital IHCA risk-standardization model (22), excluding those 11 patients with an unknown initial rhythm, the expected rate of ROSC in our cohort would have been 51.2% (47 patients). With respect to the 20 patients who did not survive to 30 days after ROSC, 12 (60.0%) had DNR orders placed after the first arrest. In the 15 who did survive to 30 days, nearly half were still in the ICU (46.7%) at that time, and 11 (73.3%) survived to hospital discharge, which occurred at a median of 33 days after IHCA. Most of these patients who survived to hospital discharge went home with good neurologic function (72.7% with CPC scores of 1 or 2). For comparison, the survival-to-discharge rate after CPR in 2018 at our medical center was 19.94% (unpublished data).

TABLE 2.
Patient Characteristics at the Time of In-Hospital Cardiac Arrest in 2020 Cohort

Variable	All ($n = 103$)	30-d Nonsurvivors ($n = 88$)	30-d Survivors ($n = 15$)	p[a]
Location of arrest, *n* (%)				0.528
Emergency department	1 (1.0)	1 (1.1)	0 (0.0)	
Standard ICU	43 (41.7)	35 (39.8)	8 (53.3)	
Surge ICU	23 (22.3)	19 (21.6)	4 (26.7)	
Ward	36 (35.0)	33 (37.5)	3 (20.0)	
Initial rhythm, *n* (%)[b]				0.646
Asystole	35 (34.0)	29 (33.0)	6 (40.0)	
Pulseless electrical activity	48 (46.6)	40 (45.5)	8 (53.3)	
Ventricular fibrillation	3 (2.9)	3 (3.4)	0 (0.0)	
Ventricular tachycardia	6 (5.8)	5 (5.7)	1 (6.7)	
Unknown	11 (10.7)	11 (12.5)	0 (0.0)	
Suspected etiology, *n* (%)[c]				< 0.001
Acute cardiovascular event	8 (7.8)	8 (9.1)	0 (0.0)	
Acute respiratory event	38 (36.9)	24 (27.3)	14 (93.3)	
Mixed	8 (7.8)	8 (9.1)	0 (0.0)	
Hypoxemia refractory to high flow nasal cannula/ non-rebreather mask	12 (11.7)	12 (13.6)	0 (0.0)	
Hypoxemia refractory to mechanical ventilation	9 (8.7)	9 (10.2)	0 (0.0)	
Refractory shock	16 (15.5)	15 (17.0)	1 (6.7)	
Unknown or other	12 (11.7)	12 (13.6)	0 (0.0)	
Days from admission to arrest, median (IQR)	8.6 (3.6–18.2)	7.2 (3.2–15.2)	22.3 (7.7–30.4)	0.008
Organ dysfunctions at time of arrest				
Mechanical ventilation, *n* (%)	71 (68.9)	57 (64.8)	14 (93.3)	0.033
Days on ventilator at time of arrest, median (IQR)[d]	10.2 (2.9–17.8)	7.7 (2.7–14.1)	22.2 (13.5–29.8)	0.006
Vasopressor therapy, *n* (%)	57 (55.3)	49 (55.7)	8 (53.3)	1
Left ventricular systolic dysfunction, *n* (%)[e]	17 (16.5)	15 (17.0)	2 (13.3)	1
Renal replacement therapy, *n* (%)	35 (34.0)	30 (34.1)	5 (33.3)	1

IQR = interquartile range.

[a]For continuous variables, *p* values were derived from either the *t* test or Wilcoxon rank-sum test, while χ^2 or Fisher exact testing was used for categorical variables.

[b]Initial rhythm data were gathered from electronic health record notes describing in-hospital cardiac arrest (IHCA).

[c]See Supplemental Methods (http://links.lww.com/CCX/A878) for further description of how suspected arrest etiologies were determined.

[d]Those who suffered IHCA on the day of intubation were excluded from this calculation.

[e]Defined as left ventricular ejection fraction ≤ 40% on most recent transthoracic echocardiogram prior to IHCA.

Spring 2021 Cohort

Between March 1, 2021, and May 31, 2021, when hospital capacity was less strained, there were 896 patients hospitalized with COVID-19 at our medical center (Fig. 1), 85 (9.5%) of whom experienced IHCA. Of these, 26 (30.6%) received CPR, 56 (65.9%) had DNR orders in place at the time of arrest, 2 (2.4%) experienced brain death, and 1 (1.2%) had missing data. Of those who received CPR, 15 (57.7%) had ROSC, 3 (11.5%) survived to 30 days post-IHCA, and 2 (7.7%) survived to hospital discharge (Table 3).

TABLE 3.
Patient Outcomes After Advanced Cardiac Life Support Resuscitation

Variable	2020 Cohort (*n* = 103)	2021 Cohort (*n* = 26)
Sustained return of spontaneous circulation achieved, *n* (%)[a]	35 (34.0)	15 (57.7)
Survival at 30 d after arrest, *n* (%)	15 (14.6)	3 (11.5)
Survival at discharge after arrest, *n* (%)	11 (10.7)	2 (7.7)
Location at 30 d after cardiac arrest in those still alive, *n* (%)		
Floor	5 (33.3)	3 (100.0)
Home	2 (13.3)	0
ICU[b]	7 (46.7)	0
Long-term acute rehabilitation	1 (6.7)	0
Survival-to-discharge outcomes		
Days from arrest to DC alive, mean (SD)	33.4 (15.1)	43.7 (2.1)
DC location, *n* (%)		
Home	3 (27.3)	1 (50.0)
Long-term acute rehab	1 (9.1)	0
Subacute rehabilitation facility/skilled nursing facility	7 (63.6)	1 (50.0)
Cerebral Performance Category on discharge, *n* (%)[c]		
Group 1–2	8 (72.7)	2 (100.0)
Group 3–4	3 (27.3)	0

DC = discharge

[a]Defined as return of spontaneous circulation that was sustained for at least 20 min.

[b]ICU location included both traditional and "surge" ICUs.

[c]Cerebral Performance Category (CPC) scores span from 1 to 5, with lower scores indicating lesser disability. For the purposes of our study, a favorable neurologic outcome was defined as a CPC score of 1 (good cerebral performance or minor disability) or 2 (moderate disability). A CPC score of 5 indicates brain death, while a CPC score of 4 is defined as a coma or vegetative state, and CPC score of 3 indicates severe disability.

Excluding those three patients with an unknown initial rhythm, the expected ROSC in this cohort based on the GWTGR IHCA risk-standardization model was 50.1% (22).

Those who survived to 30 days post-IHCA were younger (46.3 vs 67.8; $p = 0.03$), but otherwise baseline characteristics were similar (**Table 4**). The most common initial rhythms were again pulseless electric activity (65.4%) followed by asystole (19.2%; **Table 5**). While a small sample size makes comparisons difficult, there did not appear to be significant differences between those who did and did not survive to 30 days post-IHCA with respect to location, etiology, or other characteristics at the time of arrest. In pooled 2020 and 2021 data, those who survived to 30 days post-arrest were again younger ($p = 0.001$), and were still more likely to have an acute respiratory event preceding IHCA ($p = 0.001$; **Supplement Tables 4** and **5**, http://links.lww.com/CCX/A878). Both patients in the 2021 cohort who survived to discharge left the hospital with CPC scores of 2 or less (Table 3).

DISCUSSION

We found low rates of survival to 30 days and discharge among patients with COVID-19 who received CPR after IHCA in cohorts of patients admitted to CUIMC in spring 2020 and spring 2021. Compared with similar studies, our survival rates were higher than most of those reported with similar numbers of patients (10–14) and comparable to those of two larger multicenter studies which each reported a ~12% rate of survival to discharge (16, 17). Notably, we found that patients who

TABLE 4.
Baseline Characteristics of Patients Who Underwent Advanced Cardiac Life Support Resuscitation for In-Hospital Cardiac Arrest in 2021 Cohort

Variable	All ($n = 26$)	30-d Nonsurvivors ($n = 23$)	30-d Survivors ($n = 3$)
Age, mean (SD)	65.4 (16.7)	67.8 (14.5)	46.3 (23.6)
Male gender, *n* (%)	17 (65.4)	16 (69.6)	1 (33.3)
Race/ethnicity, *n* (%)[a]			
Asian	0 (0.0)	0 (0.0)	0 (0.0)
Black	6 (23.1)	6 (26.1)	0 (0.0)
Hispanic/Latino	14 (53.8)	11 (47.8)	3 (100.0)
Other	0 (0.0)	0 (0.0)	0 (0.0)
Unknown	2 (7.7)	2 (8.7)	0 (0.0)
White	4 (15.4)	4 (17.4)	0 (0.0)
Body mass index, median (interquartile range)[b]	29.3 (23.9–32.0)	28.3 (24.1–32.2)	31.3 (27.1–31.7)
Hospitalization month, *n* (%)			
March	15 (57.7)	13 (56.5)	2 (66.7)
April	8 (30.8)	8 (34.8)	0 (0.0)
May	3 (11.5)	2 (8.7)	1 (33.3)
Coronary artery disease, *n* (%)[c]	5 (19.2)	4 (17.4)	1 (33.3)
Congestive heart failure, *n* (%)[c]	9 (34.6)	8 (34.8)	1 (33.3)
Diabetes, *n* (%)[c]	12 (46.2)	9 (39.1)	3 (100.0)
Hypertension, *n* (%)[c]	13 (50.0)	11 (47.8)	2 (66.7)
Chronic kidney disease, *n* (%)[c]	5 (19.2)	5 (21.7)	0 (0.0)
Pulmonary disease, *n* (%)[c]	6 (23.1)	5 (21.7)	1 (33.3)
Active malignancy, *n* (%)[c]	3 (11.5)	3 (13.0)	0 (0.0)

[a]Data on race and ethnic group, as reported by the patient, were obtained from the clinical data warehouse.
[b]The body mass index is the weight in kilograms divided by the square of the height in meters.
[c]Comorbidity data were gathered from physician history and physical notes at the time of hospital admission prior to in-hospital cardiac arrest. Chronic kidney disease referred to stages III through V. Pulmonary disease included chronic obstructive pulmonary disease, asthma, obstructive sleep apnea, interstitial lung disease, and bronchiectasis.

experienced IHCA due to acute respiratory events had more favorable outcomes, and the rates of patients experiencing IHCA and ROSC were both improved in 2021 when CUIMC was not experiencing crisis conditions.

As in these previous studies, our IHCA survival-to-discharge rate was lower than that reported in the GWTGR, which cites survival to discharge of 26.4% after non-COVID–related IHCA (18). Our ROSC percentage was also lower than that predicted by the GWTGR IHCA risk-standardization model in our 2020 cohort; however, the comorbidity burden in our patients exceeded that of those used to generate the model (22), perhaps partially explaining this discrepancy. In our 2021 cohort, our ROSC percentage exceeded that of the model. Survival to discharge in both our cohorts was lower than that seen at our own medical center 2 years before the pandemic (unpublished data), suggesting that crisis conditions alone do not explain our low observed survival after IHCA in COVID-19 patients.

In the United States, the COVID-19 pandemic has disproportionately impacted communities of color (23). Our study findings are consistent with this fact as more than half of patients who received CPR for IHCA identified as Hispanic/Latino or African American. Despite the higher prevalence of severe COVID-19 and death

TABLE 5.
Patient Characteristics at the Time of In-Hospital Cardiac Arrest in 2021 Cohort

Variable	All (*n* = 26)	30-d Nonsurvivors (*n* = 23)	30-d Survivors (*n* = 3)
Location of arrest			
Emergency department	2 (7.7)	2 (8.7)	0 (0.0)
Standard ICU	20 (76.9)	18 (78.3)	2 (66.7)
Surge ICU	0 (0.0)	0 (0.0)	0 (0.0)
Ward	4 (15.4)	3 (13.0)	1 (33.3)
Initial rhythm, *n* (%)[a]			
Asystole	5 (19.2)	5 (21.7)	0 (0.0)
Pulseless electrical activity	17 (65.4)	14 (60.9)	3 (100.0)
Ventricular fibrillation	0 (0.0)	0 (0.0)	0 (0.0)
Ventricular tachycardia	1 (3.8)	1 (4.3)	0 (0.0)
Unknown	3 (11.5)	3 (13.0)	0 (0.0)
Suspected etiology, *n* (%)[b]			
Acute cardiovascular event	5 (19.2)	3 (13.0)	2 (66.7)
Acute respiratory event	6 (23.1)	5 (21.7)	1 (33.3)
Mixed	4 (15.4)	4 (17.4)	0 (0.0)
Hypoxemia refractory to high flow nasal cannula/ non-rebreather mask	2 (7.7)	2 (8.7)	0 (0.0)
Hypoxemia refractory to mechanical ventilation	1 (3.8)	1 (4.3)	0 (0.0)
Refractory shock	5 (19.2)	5 (21.7)	0 (0.0)
Unknown or other	3 (11.5)	3 (13.0)	0 (0.0)
Days from admission to arrest, median (IQR)	11.5 (6.7–35.1)	11.0 (5.1–38.3)	23.6 (16.3–23.6)
Organ dysfunctions at time of arrest			
Mechanical ventilation, *n* (%)	19 (73.1)	17 (73.9)	2 (66.7)
Days on ventilator at time of arrest, median (IQR)[c]	7.9 (1.2–20.5)	7.9 (1.1–22.5)	6.6 (4.4–8.7)
Vasopressor therapy, *n* (%)	19 (73.1)	17 (73.9)	2 (66.7)
Left ventricular systolic dysfunction, *n* (%)[d]	7 (26.9)	6 (26.1)	1 (33.3)
Renal replacement therapy, *n* (%)	14 (53.8)	11 (47.8)	3 (100.0)

IQR = interquartile range.

[a]Initial rhythm data were gathered from electronic health record notes describing in-hospital cardiac arrest (IHCA).

[b]See Supplemental Methods (http://links.lww.com/CCX/A878) for further description of how suspected arrest etiologies were determined.

[c]Those who suffered IHCA on the day of intubation were excluded from this calculation.

[d]Defined as left ventricular ejection fraction ≤ 40% on most recent transthoracic echocardiogram prior to IHCA.

among these communities, our findings do not show that their outcomes after CPR differ from those of other races/ethnicities.

We have found several patient characteristics that were associated with survival following ICHA. Patients who survived to 30 days after IHCA were typically younger, and in pooled data, most of them had a reversible acute respiratory event. Furthermore, patients who suffered IHCA late into their hospital stay were more likely to survive than those who arrested early. Compared with nonsurvivors, a higher proportion of patients in the 2020 cohort who survived to 30 days post-arrest were receiving mechanical ventilation at the time of IHCA. Taken together, these data suggest that 30-day survivors in the spring 2020 crisis conditions most often had etiologies related to acute complications

of mechanical ventilation that are potentially reversible, while nonsurvivors usually had IHCA etiologies attributable to the natural history of severe COVID-19. There were significantly fewer acute respiratory events in our spring 2021 cohort, perhaps reflecting fewer device and provider-related complications, such as mucus plugging of endotracheal tubes, due to decreased strain in the hospital system at that time. While most survivors in our 2020 cohort suffered acute respiratory events, barely more than one-third of all patients with this etiology survived. Of note, the likelihood of survival among these patients did not appear to be related to comorbidities in either cohort. Etiologies are not extensively discussed in most previously published studies regarding IHCA and COVID-19, which list them as "cardiac," "respiratory," or "metabolic," or none at all (10–16).

Patient-centered outcomes, such as functional status and quality of life, are more highly valued than survival by some patients (24). To inform discussions around goal-concordant care, we calculated CPC scores at time of discharge to assess neurologic outcomes after IHCA. In our study, 72.7% of patients in the 2020 cohort and all patients in the 2021 cohort who survived to discharge after an IHCA were discharged with good functional status (CPC scores of 1 or 2), which is similar to what is reported in GWTGR data (18). A CPC score in this range indicates a functional status that allows for performing activities of daily living independently (20). Furthermore, after IHCA, a CPC score of 1 or 2 at hospital discharge is associated with a 74% and 55% 5-year survival, respectively (25).

As part of CUIMC's response to the spring 2020 surge, palliative care teams were deployed to the ED and COVID-19 intermediate care units, where they oversaw hundreds of goals-of-care discussions with patients and families (26). This effort made goals-of-care conversations a routine part of COVID-19 patient-centered care and shifted discussions to earlier in patients' hospital stays. These interventions translated into DNR orders in 80.5% of patients prior to IHCA. At this time in the pandemic, CUIMC was operating at crisis capacity (2, 21), with significant PPE and ICU bed shortages. Despite these constraints and concerns regarding risks to providers during CPR (27), no patient was unilaterally made DNR by the care team against patient or surrogate wishes. It is also worth highlighting that despite the need to create surge ICUs, IHCA survival was no worse in these units.

CUIMC was not operating in crisis conditions in spring 2021 and palliative care teams were not deployed in the same fashion at that time. DNR orders were placed on 65.9% of patients prior to IHCA in this cohort, again never unilaterally. Since most providers were vaccinated against COVID-19 and nurse/respiratory therapist-to-patient ratios were back to normal, more provider time was spent at each patient's bedside in spring 2021. This perhaps explains why the frequency of acute respiratory events decreased in this cohort. It also, along with the improvement in evidence-based care for COVID-19 patients, together help explain while hospital-wide COVID-19 mortality and ROSC rates both improved in our 2021 cohort.

Our study findings provide data to inform goals-of-care discussions. While there has been a wide range of mortality estimates published in COVID-19 patients requiring mechanical ventilation, pooled together they appear consistent with those previously reported in moderate-to-severe acute respiratory distress syndrome (28). Providers should use local pandemic conditions as well as the applicability of evidence-based therapies, overall COVID-19 patient survival, IHCA success rates and neurologic outcomes to better inform conversations about preferences pertaining to resuscitation. Our data can help personalize such discussions. While it is true that the outcomes after IHCA in the majority of patients with COVID-19 are poor, our findings suggest that there are certain circumstances that, if responded to quickly, can lead to good outcomes.

The findings of this study must be interpreted within the context of its limitations. As a retrospective, single-center investigation spanning only 6 total months between 2020 and 2021, we have not established IHCA survival causality and external validity can be questioned. Details regarding ACLS timing/quality, hospital courses leading up to IHCA, and post-arrest care were not always optimally documented in the EHR, contributing to missing data that may have influenced our findings. Furthermore, since cardiac arrest was defined only by the absence of palpable pulse, it is possible that our results were biased by some suffering only transient arrests for whom CPR and/or etiology influenced outcomes differently, although given that arrest etiology and survival did not differ for patients out of ICU versus in the ICU (where telemetry and arterial monitoring were more available) in either cohort,

any such bias would likely be minimal. Also, with no comparison group of patients without COVID-19, we cannot conclude whether ACLS outcomes were driven by changed processes of care versus COVID-19 pathophysiology, or both. Additionally, high DNR order rates possibly introduced selection bias as it is feasible that patients believed unlikely to survive an arrest were more likely after goals-of-care conversations to have a DNR order placed, thus increasing our reported survival rate for those receiving ACLS after IHCA. This may be suggested by the lower 30-day and hospital discharge survival rates in our 2021 cohort compared with 2020 when DNR rates were higher. The prevalence of DNR orders in patients with IHCA has not been widely reported; however, our proportion of COVID-19 patients with IHCA receiving CPR approached that of at least one other similar study with comparable survival data (15). Finally, as a 5-point scale, CPC has limitations in evaluating functional recovery after cardiac arrest, as each category clusters various activities together (29). However, multiple studies investigating IHCA or out-of-hospital cardiac arrest have used CPC scores of 1 to 2 to define good neurologic outcome (20, 25).

Despite these limitations, to our knowledge, this is the first study to investigate the impact of IHCA etiology and local pandemic conditions on survival among hospitalized patients with COVID-19 who received ACLS over multiple time periods. Our study provides insights that are new and relevant during the ongoing COVID-19 pandemic, which unfortunately continues to surge in different places globally and will hopefully allow for COVID-19 patients, their families, and providers to have more informed goals-of-care discussions.

CONCLUSIONS

In our cohorts, we found that most patients hospitalized with COVID-19 who received CPR did not survive to 30 days after IHCA. Most 30-day survivors experienced IHCA due to acute respiratory events. Arrest etiologies in nonsurvivors included refractory shock, refractory hypoxemia, and acute cardiovascular events in addition to acute respiratory events. ROSC was more commonly achieved in our 2021 cohort when crisis conditions were absent. These data suggest that even in a disease with high in-hospital mortality, successful ACLS resuscitation can still be provided in select situations. Further studies are needed to investigate outcomes after IHCA in patients with COVID-19 patients to help develop best practices relating to CPR appropriateness as cases continue to surge in locations worldwide.

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