Received: 12 April 2022 | Revised: 12 July 2022 | Accepted: 12 August 2022

DOI: 10.1002/ccd.30390

ORIGINAL ARTICLE - CLINICAL SCIENCE

WILEY

Characteristics and outcomes of patients presenting with acute myocardial infarction and cardiogenic shock during COVID-19

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Abstract

Objectives: To evaluate characteristics and outcomes of patients presenting with acute myocardial infarction and cardiogenic shock (AMICS) during the coronavirus disease 2019 (COVID-19) pandemic.

Background: The COVID-19 pandemic has created challenges in delivering acute cardiovascular care. Quality measures and outcomes of patients presenting with AMICS during COVID-19 in the United States have not been well described.

Methods: We identified 406 patients from the National Cardiogenic Shock Initiative (NCSI) with AMICS and divided them into those presenting before ($N = 346$, 5/9/2016–2/29/2020) and those presenting during the COVID-19 pandemic ($N = 60$, 3/1/2020–11/10/2020). We compared baseline clinical data, admission characteristics, and outcomes.

Results: The median age of the cohort was 64 years, and 23.7% of the group was female. There were no significant differences in age, sex, and medical comorbidities between the two groups. Patients presenting during the pandemic were less likely to be Black compared to those presenting prior. Median door to balloon (90 vs. 88 min, $p = 0.38$), door to support (88 vs. 78 min, $p = 0.13$), and the onset of shock to support (74 vs. 62 min, $p = 0.15$) times were not significantly different between the two groups. Patients presented with ST-elevation myocardial infarction more often during the COVID-19 period (95.0% vs. 80.0%, $p = 0.005$). In adjusted logistic regression models, COVID-19 period did not significantly associate with survival to discharge (odds ratio [OR] 1.09, 95% confidence interval [CI] 0.54–2.19, $p = 0.81$) or with 1-month survival (OR 0.82, 95% CI 0.42–1.61, $p = 0.56$).

Conclusions: Care of patients presenting with AMICS has remained robust among hospitals participating in the NCSI during the COVID-19 pandemic.

KEYWORDS

acute myocardial infarction/STEMI; coronary artery disease, intervention; mechanical circulatory support, ECMO/IABP/tandem/Impella; shock, cardiogenic

Abbreviations: ACS, acute coronary syndrome; AMICS, acute myocardial infarction and cardiogenic shock; COVID-19, coronavirus disease 2019; NCSI, National Cardiogenic Shock Initiative; PCI, percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction.

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1 | INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic has created challenges in the delivery of acute cardiovascular care. Cohorts in the United States[1–4] and internationally[5–10] have reported decreases in hospital presentations of acute coronary syndrome during the pandemic. Some studies have found worse outcomes for patients with acute coronary syndrome presenting during COVID-19,[2,11–14] which may be related to hospital processes. An English cohort, for example, found decreases in primary percutaneous coronary intervention (PCI) for ST-elevation myocardial infarction (STEMI) and delays in both symptom-to-hospital and door-to-balloon times.[11] Similar findings have also been reported in China.[12,13]

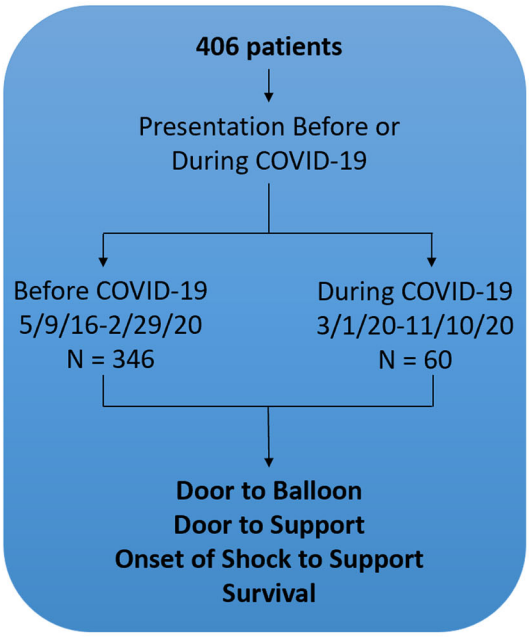
Patients presenting with acute myocardial infarction and cardiogenic shock (AMICS) have been reported to experience >30% in-hospital mortality.[15–18] Given the significant morbidity and mortality associated with AMICS, and the major disruptions to the delivery of acute cardiovascular care during the pandemic, it is essential to understand AMICS diagnostic and outcome patterns during COVID-19. Here, we analyze the clinical characteristics and outcomes of patients presenting with AMICS during COVID-19 and compare them to those of patients presenting before the COVID-19 pandemic.

2 | METHODS

2.1 | Study population

The National Cardiogenic Shock Initiative (NCSI) is a prospective, single-arm study assessing the impact of early mechanical circulatory support in patients presenting with AMICS who were treated with PCI. Data leading to the NCSI creation and enrollment details have been previously described.[18,19] Briefly, the NCSI included patients presenting with AMICS for which a physician activated the catheterization laboratory. For patients with a left ventricular end diastolic pressure greater than 15 mmHg or a Cardiac Index less than 2.2 L/min/m^2, the interventional cardiologist placed an Impella, a powerful transcatheter axial flow pump able to supply 2.5–4.0 L/min of forward systemic blood flow (Abiomed). After placement of mechanical support, coronary angiography and PCI were performed. In the catheterization laboratory, calculations of cardiac power output and pulmonary artery pulsatility index were used to guide escalation or de-escalation of pharmacologic and mechanical hemodynamic support at thresholds of 0.6 W and 0.9, respectively. The final study cohort consisted of 406 patients enrolled between May 9, 2016, and November 10, 2020, from 80 hospitals across the United States.

Our study divided the NCSI cohort into pre-COVID-19 (5/9/2016–2/29/2020) and during COVID-19 periods (3/1/2020–11/10/2020) (Figure 1). We then compared baseline clinical characteristics,



Clinical characteristics

- Median age: 64 years
- Female: 23.7%
- Prior LVEF <50%: 23.1%
- Prior PCI: 24.5%
- No significant differences in age, sex, or medical comorbidities

Hospital Times

	Before COVID-19	During COVID-19
Median Door to Balloon	90 min	88 min
Median Door to Support	88 min	78 min
Median Onset of Shock to Support	74 min	62 min

P > 0.1 for all

Outcomes

	Before COVID-19	During COVID-19
Survival to Discharge	70.2%	73.3%
Survival to One Month	68.2%	67.8%

P > 0.5 for all

FIGURE 1 Central Illustration. Acute myocardial infarction and cardiogenic shock (AMICS) during COVID-19. Presenting during the COVID-19 pandemic did not decrease the risk of survival to discharge or 1 month for patients presenting with AMICS among medical centers participating in the National Cardiogenic Shock Initiative from May 2016 to November 2020. Important quality metrics such as median door to balloon time, door to support time, and the onset of shock to support also did not significantly differ compared during the COVID-19 pandemic to prior. [Color figure can be viewed at wileyonlinelibrary.com]

admission features, and survival outcomes. We selected 3/1/2020 as the cutoff between periods as there were few COVID-19 cases in the United States before this date. As a sensitivity analysis, we repeated comparisons of patient characteristics and outcomes using an earlier COVID-19 period, set at the time of the first diagnosis of COVID-19 within the United States. In this analysis, we compared patients presenting between 5/9/2016 and 1/19/2020 to those presenting between 1/20/2020 and 11/10/2020.

Weekly decreases in AMICS presentations were calculated by comparing the number of AMICS presentations recorded in NCSI from March 1, 2020, to November 10, 2020, with March 1, 2019, to November 10, 2019. Each participating hospital enrolled patients ethically and in a manner approved by their associated Institutional Review Board as previously reported.[18]

2.2 | Statistical analysis

Patients were divided into groups based on time of presentation (pre-COVID-19 vs. during COVID-19). Demographics, baseline medical comorbidities, admission characteristics, and quality metrics, including hospital timings, were compared between the two groups using Kruskal–Wallis and χ^2 for continuous and categorical variables, respectively. To further evaluate the impact of presentation period on AMICS outcomes, logistic regression models were used. Models were adjusted for demographics (age, sex, race) and baseline medical history status (diabetes mellitus, transient ischemic attack/cerebrovascular accident, end-stage renal disease, chronic kidney disease, left ventricular ejection fraction <50%, prior coronary artery bypass grafting, prior PCI, prior myocardial infarction). Race was denoted as other if missing. The two-sided level of significance was set to $p < 0.05$. All statistical analyses were performed using Stata version 15.1 (Stata Corp LLC).

3 | RESULTS

Three hundred and forty-six patients presented pre-COVID-19, and 60 patients presented during COVID-19 (Table 1). The median age of the cohort was 64 years, and 23.7% of the group was female. There were no significant differences in age, sex, and captured cardiovascular medical comorbidities between the two groups. Patients presenting during the pandemic were less likely to be of the Black race (3.3% vs. 9.3%), and more likely to be of Hispanic (13.3% vs. 5.8%) and White race (76.7% vs. 66.8%) than patients presenting before the COVID-19 pandemic ($p = 0.011$; Table 1). Rates of

TABLE 1 Demographics and medical comorbidities of patients enrolled in NCSI stratified by coronavirus disease 2019 period

Period	Overall, *N* = 406 5/9/16–11/10/20	Before COVID-19, *N* = 346 5/9/16–2/29/20	During COVID-19, *N* = 60 3/1/20–11/10/20	*p* Value
Demographics				
Age, years	64 (55–72)	64 (55–73)	65 (55–71)	0.99
Female, *n* (%)	96 (23.7)	84 (24.3)	12 (20)	0.47
Race, *n* (%)				0.011
Black	34 (8.4)	32 (9.3)	2 (3.3)	
Hispanic	28 (6.9)	20 (5.8)	8 (13.3)	
White	277 (68.2)	231 (66.8)	46 (76.7)	
Other/not available	67 (16.5)	63 (18.2)	4 (6.7)	
Medical comorbidities				
Diabetes mellitus, *n* (%)	160 (40.4)	133 (39.5)	27 (45.8)	0.36
Prior history of TIA/CVA, *n* (%)	37 (9.4)	33 (9.9)	4 (6.7)	0.44
End-stage renal disease, *n* (%)	15 (3.8)	14 (4.1)	1 (1.7)	0.36
Chronic kidney disease, *n* (%)	50 (12.6)	40 (11.9)	10 (16.7)	0.30
Prior LVEF < 50%, *n* (%)	88 (23.1)	78 (24.1)	10 (17.5)	0.28
Prior CABG, *n* (%)	24 (6.0)	21 (6.2)	3 (5.0)	0.72
Prior PCI, *n* (%)	97 (24.5)	81 (24.1)	16 (26.7)	0.67
Prior MI, *n* (%)	79 (20.0)	66 (19.7)	13 (21.7)	0.73

Note: Continuous variables are presented as median (25th–75th percentile). Categorical variables are presented as *n* (%). Continuous and categorical variables were compared using Kruskal–Wallis and χ^2 tests, respectively.

Abbreviations: CABG, coronary artery bypass grafting; COVID-19, coronavirus disease-2019; CVA, cerebrovascular accident; LVEF, left ventricular ejection fraction; MI, myocardial infarction; *n*, frequency; PCI, percutaneous coronary intervention; TIA, transient ischemic attack; %, percentage.

TABLE 2 Admission characteristics, hospital times, and outcomes of patients enrolled in NCSI stratified by coronavirus disease 2019 period

Period	Overall, *N* = 406 5/9/16–11/10/20	Before COVID-19, *N* = 346 5/9/16–2/29/20	During COVID-19, *N* = 60 3/1/20–11/10/20	*p* Value
Admission characteristics				
Transferred from another hospital, *n* (%)	106 (26.1)	96 (27.8)	10 (16.7)	0.07
Cardiac arrest in-hospital before arrival to cath lab, *n* (%)	118 (29.1)	100 (28.9)	18 (30.0)	0.86
Cardiac arrest out of hospital before arrival to cath lab, *n* (%)	68 (16.8)	58 (16.8)	10 (16.7)	0.98
Treated with hypothermia, *n* (%)	39 (11.0)	34 (11.5)	5 (8.5)	0.5
Lactate pre-Impella, mmol/L	3.4 (2.0–6.2)	3.7 (2.0–6.7)	2.5 (2.0–5.1)	0.17
Shock on admission, *n* (%)	270 (66.7)	234 (67.8)	36 (60.0)	0.24
STEMI, *n* (%)	333 (82.2)	276 (80.0)	57 (95.0)	0.005
Hospital times				
Door to balloon time, min	89 (60–137)	90 (58–146)	88 (67–108)	0.38
Door to support time, min	87 (58–156)	88 (58–159)	78 (59–111)	0.13
Onset of shock to support time, min	71 (31–116)	74 (34–119)	62 (27–98)	0.15
Outcomes				
Index procedure survival, *n* (%)	400 (98.5)	341 (98.6)	59 (98.3)	0.9
Survival to discharge, *n* (%)	287 (70.7)	243 (70.2)	44 (73.3)	0.63
One-month survival, *n* (%)	272 (68.2)	232 (68.2)	40 (67.8)	0.95

Note: Continuous variables are presented as median (25th–75th percentile). Categorical variables are presented as *n* (%). Continuous and categorical variables were compared using Kruskal–Wallis and χ^2 tests, respectively.

Abbreviations: COVID-19, coronavirus disease-2019; L, liter; mmol, millimole; *n*, frequency; STEMI, ST-elevation myocardial infarction; %, percentage.

missingness are described in Supporting Information: Table 1S. Presentations of AMICS decreased by 44.5% when comparing the pre- to the during COVID-19 period (Supporting Information: Figure 1S).

Quality metrics of in-hospital times were compared between the two groups (Table 2). Door to balloon (90 vs. 88 min, $p = 0.38$), door to support (88 vs. 78 min, $p = 0.13$), and onset of shock to support (74 vs. 62 min, $p = 0.15$) times were not significantly different when comparing those who presented before those who presented during the pandemic.

Characteristics of AMICS admissions are also described (Table 2). Rates of cardiac arrest before arrival in the cardiac catheterization lab were not significantly different between the two groups. Rates of treatment with hypothermia were also similar. There was a trend toward a decrease in presentation as a transfer from another hospital during COVID-19 compared to prior, which was statistically nonsignificant (16.7% vs. 27.8%, $p = 0.07$). Presentations with STEMI were increased during the COVID-19 period (95.0% vs. 80.0%, $p = 0.005$). Presence of shock on admission (67.4% vs. 60.0%, $p = 0.24$) and median serum lactate before mechanical circulatory support with Impella placement (3.7 mmol/L [2.0–6.7] vs. 2.5 [2.0–5.1] during COVID-19; $p = 0.17$) were not statistically significantly different pre-COVID-19 compared to during the COVID-19 pandemic.

To assess the association of presentation period with survival in our cohort, we performed logistic regression analyses (Table 3). In adjusted logistic regression models, COVID-19 time period did not significantly associate with survival to discharge (odds ratio [OR]: 1.09, 95% confidence interval [CI]: 0.54–2.19, $p = 0.81$), or with survival at 1-month (OR: 0.82, 95% CI: 0.42–1.61, $p = 0.56$). In sensitivity analysis, repeating the analysis above using the date of first COVID-19 diagnosis in the United States as the start date for the during COVID-19 group yielded no significant differences in quality metrics or outcomes (Supporting Information: Tables 2S and 3S).

4 | DISCUSSION

In this national analysis of 406 patients from 80 US hospitals, we show a 44.5% decrease in AMICS presentations during COVID-19 when compared to similar months the year prior. Hospital quality metrics, including door to support, onset of shock to support, and door to balloon times, were similar among those presenting pre- and during the pandemic. In adjusted models, COVID-19 time period did not associate with patient outcomes, including survival to discharge and survival at 1 month. Of note, we did find a significantly higher proportion of patients presenting with STEMI during the COVID-19 pandemic. Overall, our findings suggest that the care of patients

TABLE 3 Association of period (pre-COVID-19 vs. during COVID-19) with survival of patients enrolled in NCSI presenting with acute myocardial infarction and cardiogenic shock

Outcome[a]	Unadjusted OR [95% CI]	*p* Value	Adjusted[b] OR [95% CI]	*p* Value
Survival to discharge	1.17 [0.63–2.16]	0.63	1.09 [0.54–2.19]	0.81
Survival at 1 month	0.98 [0.54–1.77]	0.94	0.82 [0.42–1.61]	0.56

Abbreviations: CI, confidence interval; COVID-19, coronavirus disease-2019; OR, odds ratio.

[a]Logistic regression models compared during the COVID-19 period to pre-COVID-19 (reference).

[b]Regression models adjusted for age, sex, race, and medical comorbidities (history of diabetes, transient ischemic attack/cerebrovascular accident, end-stage renal disease, chronic kidney disease, left ventricular ejection fraction <50%, prior coronary artery bypass grafting, prior percutaneous coronary intervention, prior myocardial infarction).

presenting with AMICS remained robust among hospitals taking part in the NCSI during the COVID-19 pandemic.

To our knowledge, this is the first analysis of AMICS epidemiology and mortality outcomes during the COVID-19 pandemic in the US population. One publication of AMICS incidence during the COVID-19 era using Danish data has been previously reported.[20] These authors found no significant difference in the incidence of AMICS from a larger patient population (>13,000 patients) studied for a shorter period of time (during COVID-19 group ending in May 2020).[20] In our national US cohort, we demonstrate decreased presentations for AMICS, which is congruent with prior data in the United States demonstrating decreased presentations for acute coronary syndrome.[1–3] Decreased presentations and delayed presentations of STEMI have also been suspected globally by physicians, with the majority surveyed reporting >40% reduction in STEMI presentations.[8]

Similar to the results from the Denmark national registries, we found no significant difference in hospital process measures or in-hospital mortality.[20] As the underlying biology and natural progression of coronary artery disease to acute myocardial infarction would not be expected to change significantly in the period of study by our group and our Danish colleagues, it is possible that our observed decrease in AMICS presentations relates to differences in behavioral decisions about seeking healthcare. The significantly higher number of COVID-19 cases present in the United States (10 million cases, 3.11% population infected), when compared to Denmark (57 thousand cases, 0.99% population infected) during the period studied, likely had an influence on patient decisions to present for medical care.[21–23] In a behavioral study surveying 2201 adults across the United States from April 18 to April 20, 2020, 29% of US adults surveyed reported actively delaying or avoiding medical care due to concerns for contracting COVID-19.[24] This sentiment appears to have sustained as 12.0% of 4975 US adults surveyed by the Center for Disease Control from June 24 to June 30, 2020, reported to have delayed or avoided urgent or emergency medical care.[25] Delays in US adults seeking medical care during our COVID-19 pandemic period of study has been similarly reported in multiple additional publications and surveys such as the US Census "Household Pulse Survey."[26]

One possible explanation for the higher percentage of cases presenting with STEMI in the NCSI cohort during the COVID-19 pandemic is that some patients with acute coronary syndrome may have delayed presenting to the hospital until symptoms further progressed. This possibility is consistent with a single center study that reported time from symptoms to hospital admission was significantly prolonged in patients with STEMI during COVID-19 compared to a historical cohort.[27] Although a higher percentage of patients in the NCSI cohort presented with STEMI during COVID-19, we did not observe additional signs of decompensation by other metrics such as the presence of shock on admission or higher serum lactate before mechanical support.

Although, to our knowledge, Lauridsen et al.[20] and our manuscript are the only two reports examining AMICS, other studies have examined the incidence, characteristics, and outcomes of acute myocardial infarction during the COVID-19 pandemic. Presentations, outcomes, and management of acute coronary syndrome (ACS) have differed across the globe during the pandemic. At a single center in Wuhan, China, Huang et al.[12] found a fourfold increase in all-cause mortality in patients presenting with STEMI in the first two months of the COVID-19 pandemic compared to the prior year. These patients presenting with STEMI had increased time from symptoms to intervention, as well as a relative increase in emergency thrombolysis and decrease in primary PCI.[12] A tertiary medical center in Germany also found increased complications and mortality among patients presenting with acute myocardial infarction during the early stage of the COVID-19 pandemic.[14]

Data from other countries have differed from the findings reported from China and Germany. In a cohort of more than 30,000 patients presenting with STEMI across 44 healthcare centers in England, no significant difference was found for multivariable-adjusted in-hospital death or major adverse cardiovascular events despite significantly less use of PCI and longer door-to-balloon times in patients who did undergo PCI.[11] Interestingly, a regional US analysis of acute myocardial infarction before and during the COVID-19 pandemic found no differences in treatment approach, but did find significantly increased observed deaths compared to expected deaths for patients presenting with STEMI.[2] These publications reporting data from three different continents suggest that at least in some populations and health systems, broad trends

toward worse hospital quality measures, and in some instances, higher mortality burden were observed during the immediate phase of the COVID-19 pandemic for acute coronary syndrome and its complications.

Considering noted trends toward worse process measures and outcomes for acute coronary syndrome during the COVID-19 pandemic, our study importantly notes no significant difference in quality metrics for timeliness of care or mortality in AMICS. One possible explanation of our findings may be the high-fidelity use of prespecified protocols for patients enrolled in NCSI. These protocols may have helped maintain quality of care in the setting of acute cardiovascular disease such as AMICS, particularly during a prolonged systemically disruptive event such as the COVID-19 pandemic. Medical centers participating in NCSI by necessity had active review of their cardiac catheterization activation protocols, and a prespecified quality measure of the door to mechanical support time of less than 90 min.[19]

Protocols are widely accepted across medicine, and have demonstrated improved patient outcomes in broad disciplines of healthcare, including nursing,[28] surgery,[29] obstetrics,[30] sepsis,[31] and cardiogenic shock.[15] Other acute conditions with highly protocolized management structures such as stroke have also noted similar procedure times and outcomes during the pandemic.[32] Of note, our findings are in part contrasted to another group within the United States studying care of cardiogenic shock who reported disruptions in management, increased declination of transfers to a tertiary medical center, higher median serum lactate, and a statistically nonsignificant trend toward worse mortality in patients declined for transfer.[33] One possible explanation for this difference reported may have been the modification of transfer acceptance to be more restrictive when critical care resources were limited. A 42% declination for transfer rate from March 1 to June 30, 2020 (during COVID-19) compared to an 11% declination rate before the COVID-19 pandemic was reported.[33] Although medical centers taking part in NCSI were also stressed by surges in COVID-19 infection, there was no explicit modification of protocol regarding presentations appropriate for transfer to a left ventricular assist device or cardiac transplantation center.

4.1 | Study limitations

Our study is limited by its retrospective, observational nature. We can only evaluate associations and not causality. Though we adjusted for medical comorbidities in our regression models, the potential for residual confounding remains. COVID-19 infection status at the time of presentation with AMICS or following presentation is not available in NCSI, and so we are unable to comment on how the care of AMICS patients differed between those infected and not infected with COVID-19. Our data come from sites enrolled in the NCSI and only applies to patients who present with ACS and cardiogenic shock, and therefore may not be readily generalizable to the broader US population. However, the NCSI does include a diverse array of medical centers throughout the United States ranging from predominantly private to largely academic.

5 | CONCLUSIONS

Among hospitals participating in the NCSI, patients presenting with AMICS during the COVID-19 pandemic received similar quality of care and experienced similar risk-adjusted outcomes when compared with patients with AMICS presenting before the COVID-19 pandemic. These findings show that in NCSI centers with highly protocolized management pathways, AMICS care has remained robust during the COVID-19 pandemic.

ACKNOWLEDGMENT

Henry Ford Health System sponsored the National Cardiogenic Shock Initiative (clinical trial NCT03677180) with Collaboration from Abiomed Inc. and Chiesi Farmaceutici S.p.A. No funding supported the following manuscript.

CONFLICTS OF INTEREST

Drs. Basir and O'Neill have consultant relationships with Abbott Vascular, Abiomed, Cardiovascular Systems, Chiesi, and Zoll. The remaining authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Ahlers MJ, Srivastava PK, Basir MB, et al. Characteristics and outcomes of patients presenting with acute myocardial infarction and cardiogenic shock during COVID-19. *Catheter Cardiovasc Interv*. 2022;1-7. doi:10.1002/ccd.30390