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Original Research

Impact of Socioeconomic Status on Mechanical Circulatory Device Utilization and Outcomes in Cardiogenic Shock

Andrew Adelsheimer, MD, MBA [a,*], Joseph Wang, MD [b], Daniel Y. Lu, MD [b], Lindsay Elbaum, MD [b], Udhay Krishnan, MD [b,c], Jim W. Cheung, MD [b,c], Dmitriy N. Feldman, MD [b,c], S. Chiu Wong, MD [b], Evelyn M. Horn, MD [b], Irina Sobol, MD [b], Parag Goyal, MD, MSc [b,a], Maria G. Karas, MD [b], Luke K. Kim, MD [b,c]

[a] *Division of General Internal Medicine, Department of Medicine, Weill Cornell Medical College, NewYork-Presbyterian Hospital, New York, New York*
[b] *Division of Cardiology, Department of Medicine, Weill Cornell Medical College, NewYork-Presbyterian Hospital, New York, New York*
[c] *Weill Cornell Cardiovascular Outcomes Research Group, Weill Cornell Medical College, New York, New York*

A B S T R A C T

Objectives: This study evaluates the impact of socioeconomic status (SES) on utilization of mechanical circulatory support (MCS) devices and outcomes in cardiogenic shock (CS).

Background: CS is associated with significant mortality. There is increasing use of temporary MCS devices in CS, and its impact on outcomes is currently under investigation. There is a lack of data on the effect of SES on the utilization of MCS devices in CS.

Methods: CS hospitalizations were obtained from the State Inpatient Databases in 2016 from 9 states representing various regions in the United States. The study had exempt institutional review board status as the database includes deidentified data. Hospitalizations were separated into SES cohorts based on the median household income of the patient residence zip code. Utilization of MCS devices and revascularization procedures along with clinical outcomes with CS were compared across the quartiles.

Results: There were 38,520 hospitalizations identified with CS, 42.6% of which were secondary to acute myocardial infarction. Patients from higher SES areas were significantly older but had lower burden of comorbidities. Utilization of temporary MCS devices was higher for hospitalizations from higher SES regions (frequency from the lowest SES quartile to the highest SES quartile: 21.3%, 21.5%, 23.5, and 24.1%, $P < .01$), though revascularization rates were similar. However, there was no significant difference in overall mortality from CS among the 4 quartiles. Patients from regions of higher SES experienced increased hospital costs.

Conclusions: Higher SES regions had increased use of temporary MCS. There was no difference in mortality between SES cohorts.

Introduction

Cardiogenic shock (CS) is a rapidly progressive disease state, often complicated by multiorgan failure. Although the overall incidence of CS is relatively low (~4% after acute myocardial infarction [AMI] and <5% of decompensated heart failure hospitalizations), CS is still associated with significant morbidity and mortality.[1-3] While the historical mortality rate associated with CS is high, timely revascularization for those presenting with AMI has resulted in reduction of the mortality rate to near 50% in recent years.[2-7] However, further reductions in mortality have plateaued, partly due to increasing patient comorbidities and rising proportions of CS not associated with AMI (non-AMI-CS).[7-11]

In order to further improve outcomes in those presenting with CS, recent efforts in the management of CS have focused on developing shock protocols, teams, and regional systems to effectively coordinate care and facilitate therapies.[9,10,12] Treatment strategies hinge on rapid triage with early invasive hemodynamic monitoring and mechanical circulatory support (MCS) devices.[13-15] Although randomized trials failed to demonstrate mortality benefits of temporary MCS in AMI-CS, several studies have suggested that targeted use of mechanical support may

Abbreviations: AMI, acute myocardial infarction; CS, cardiogenic shock; ECMO, extracorporeal membrane oxygenation; HCUP, Healthcare Cost and Utilization Project; IABP, intra-aortic balloon pump; LVAD, left ventricular assist device; MCS, mechanical circulatory support; SES, socioeconomic status; SID, State Inpatient Databases.

Keywords: Cardiogenic shock; socioeconomic status; mechanical circulatory support.

* Corresponding author.
E-mail address: aja9014@nyp.org (A. Adelsheimer).

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Table 1. Baseline characteristics of patients hospitalized with cardiogenic shock.

	Socioeconomic status quartile				
	First quartile	Second quartile	Third quartile	Fourth quartile	*P*-value
Number of patients	n = 11,578	n = 10,176	n = 8829	n = 7937	
Demographic					
Age, years	65.8 (0.1)	67.2 (0.2)	67.5 (0.2)	69.4 (0.2)	<.01
Female sex	4603 (39.8%)	3844 (37.8%)	3286 (37.2%)	2907 (36.6%)	<.01
Race					<.01
White	6322 (54.6%)	7213 (70.9%)	6512 (73.8%)	5909 (74.4%)	
Black	2947 (25.5%)	1325 (13.0%)	982 (11.1%)	709 (8.9%)	
Hispanic	1382 (11.9%)	816 (8.0%)	522 (5.9%)	418 (5.3%)	
Asian or Pacific Islander	123 (1.1%)	163 (1.6%)	225 (2.5%)	304 (3.8%)	
Native American	132 (1.1%)	44 (0.4%)	32 (0.4%)	25 (0.3%)	
Other/missing	672 (5.8%)	615 (6.0%)	556 (6.3%)	572 (7.2%)	
Primary payer					<.01
Medicare	7046 (60.9%)	6415 (63.1%)	5548 (62.9%)	5092 (64.2%)	
Medicaid	4603 (16.0%)	3844 (11.6%)	3286 (9.8%)	2907 (6.3%)	
Private	1981 (17.1%)	1981 (19.5%)	1977 (22.4%)	2036 (25.7%)	
Comorbidities					
Elixhauser comorbidities >4	5327 (46.0%)	4442 (43.7%)	3845 (43.6%)	3183 (40.1%)	<.01
Atrial fibrillation	3708 (32.0%)	3367 (33.1%)	2899 (32.8%)	2730 (34.4%)	<.01
Valvular disease	887 (7.7%)	814 (8.0%)	685 (7.8%)	677 (8.5%)	.07
Chronic pulmonary disease	3368 (31.7%)	2950 (29.0%)	2365 (26.8%)	1786 (22.5%)	<.01
Pulmonary circulation disorders	218 (1.9%)	229 (2.3%)	224 (2.5%)	159 (2.2%)	.10
Renal failure	4337 (37.5%)	3632 (35.7%)	3145 (35.6%)	2764 (34.8%)	<.01
Liver disease	786 (6.8%)	600 (5.9%)	470 (5.3%)	413 (5.2%)	<.01
Hypertension	7132 (61.6%)	6207 (61.0%)	5278 (59.8%)	4693 (59.1%)	<.01
Hyperlipidemia	4922 (42.5%)	4527 (44.6%)	4127 (46.7%)	3637 (45.8%)	<.01
Obesity	2329 (20.1%)	1885 (18.5%)	1517 (17.2%)	1121 (14.1%)	<.01
Diabetes	4569 (39.6%)	3797 (37.3%)	3297 (37.3%)	2797 (35.3%)	<.01
Other neurological disorders	1278 (11.0%)	1124 (11.0%)	978 (11.1%)	808 (10.2%)	.10
Malignancy	179 (1.5%)	193 (1.9%)	186 (2.1%)	198 (2.5%)	<.01
Hypothyroidism	1408 (12.2%)	1302 (12.8%)	1249 (14.1%)	1151 (14.5%)	<.01
Fluid and electrolyte disorders	7335 (63.4%)	6471 (63.6%)	5845 (66.2%)	5303 (66.8%)	<.01
Rheumatoid arthritis/collagen vascular disease	286 (2.5%)	293 (2.9%)	262 (3.0%)	224 (2.8%)	.08
Depression	1028 (8.9%)	1005 (9.9%)	865 (9.8%)	656 (8.3%)	.31
Alcohol abuse	808 (7.0%)	619 (6.1%)	469 (5.3%)	330 (4.2%)	<.01
Drug abuse	587 (5.1%)	362 (3.6%)	309 (3.5%)	198 (2.5%)	<.01
Coronary artery disease history	6672 (57.6%)	5934 (58.3%)	5106 (57.8%)	4553 (57.4%)	.67
Prior myocardial infarction	1662 (14.4%)	1396 (13.7%)	1234 (14.0%)	1032 (13.0%)	.02
Prior PCI	1387 (12.0%)	1192 (11.7%)	1017 (11.5%)	996 (12.6%)	.42
Prior CABG	1088 (9.4%)	986 (9.7%)	839 (9.5%)	807 (10.2%)	.13
AMI on presentation	4765 (41.2%)	4400 (43.2%)	3825 (43.3%)	3410 (43.0%)	.01

Values are presented as number (percentage) for categorical values and mean (standard error of the mean) for continuous variables. Survey-specific univariate logistic regression and linear regression were used for categorical variables and numeric variables, respectively. The first quartile is the lowest socioeconomic status (SES), while the fourth quartile is the highest SES.
AMI, acute myocardial infarction; CABG, coronary artery bypass graft; PCI, percutaneous coronary intervention.

improve outcomes.[16-18] There is a paucity of data on the use of MCS in non-AMI-CS, and this area continues to be investigated with the advancements in MCS devices and technology.

MCS has an evolving role in tertiary CS care, but invasive interventions may be concentrated in regions of higher socioeconomic status (SES). Previous studies have demonstrated discrepancies in access to advanced surgical procedures based on SES for noncardiac conditions.[19,20] In addition, higher SES has been associated with increased rates of revascularization for AMI.[21] In order to assess access to advanced care in CS, we evaluated the impact of SES on temporary MCS device utilization in CS using a large-scale representative database from 2016.

Methods

Data source

The State Inpatient Database (SID) is an administrative database maintained by the Agency for Healthcare Research and Quality and the Healthcare Cost and Utilization Project (HCUP). This publicly available annual database consists of inpatient discharge records from nonfederal, community hospitals.[22] Data for this study were obtained from the 2016 SID in 9 states: Arizona, Colorado, Florida, Maryland, Michigan, North Carolina, New Jersey, New York, and Washington. In the year 2016, this subset of the SID contained deidentified information for 11,003,147 total discharges (AZ—735,890, CO—480,573, FL—2,837,863, MD—622,815, MI—1,240,053, NC—1,110,146, NJ—979,099, NY—2,347,084, and WA—649,624). Each SID patient record contains diagnoses and procedures performed during the hospitalization based on International Classification of Diseases, 10th Revision–Clinical Modification (ICD-10-CM) codes. Institutional review board approval and informed consent were not required because all data collection was obtained from a deidentified administrative database.

Study population and variables

Hospitalizations for patients aged ≥18 years with CS were identified using the ICD-10-CM code R57.0. Patients were separated into 4 SES cohorts based on the quartile of the median household income of the residence zip code, using the variable ZIPINC_QRTL, with the lowest SES labeled as the first quartile and the highest SES as the fourth quartile. We used the variable ZIP3 (first 3 numbers of the zip code) for creation of geographic maps.

Patient-level variables were collected using ICD-10-CM codes, Elixhauser comorbidity software, and intrinsic SID variables.[23] AMI was identified by ICD-10-CM diagnosis codes I21.x (excluding I21.A1 subendocardial infarction). Procedures related to CS were identified utilizing the ICD-10-CM procedure codes for percutaneous coronary intervention (PCI—027xxxx), coronary artery bypass grafting (021xxxx), intra-aortic balloon pump

Table 2. Association of socioeconomic status and outcomes with cardiogenic shock.

	Socioeconomic status quartile				
	First quartile	Second quartile	Third quartile	Fourth quartile	*P*-value
Mortality	4175 (36.1%)	3776 (37.2%)	3186 (36.1%)	3011 (37.9%)	.05
Length of stay, days	11.5 (0.1)	11.1 (0.1)	11.4 (0.2)	12.1 (0.2)	.02
Total cost, $	66,446 (825)	70,733 (1027)	79,376 (1195)	85,551 (1260)	<.01
Cardiac procedures performed					
PCI	1941 (16.8%)	1843 (18.1%)	1698 (19.2%)	1480 (18.7%)	<.01
CABG	1119 (9.7%)	926 (9.1%)	798 (9.0%)	654 (8.2%)	<.01
Mechanical circulatory support	2464 (21.3%)	2192 (21.5%)	2072 (23.5%)	1912 (24.1%)	<.01
IABP	1824 (15.8%)	1553 (15.3%)	1464 (16.7%)	1364 (17.2%)	<.01
Impella/TandemHeart	459 (4.0%)	462 (4.5%)	400 (4.5%)	368 (4.6%)	.02
ECMO	210 (1.8%)	194 (1.9%)	217 (2.5%)	220 (2.8%)	<.01
Single MCS device (% of MCS)	2206 (89.5%)	1918 (87.5%)	1802 (87.0%)	1662 (86.9%)	.02
Multiple MCS devices (% of MCS)	258 (11.5%)	274 (12.5%)	270 (13%)	250 (13.1%)	.02
LVAD implantation	196 (1.7%)	188 (1.9%)	159 (1.8%)	135 (1.7%)	.94
Heart transplantation	64 (0.6%)	60 (0.6%)	71 (0.8%)	66 (0.8%)	.01
Vasopressors used	993 (8.6%)	877 (8.6%)	834 (9.4%)	829 (10.4%)	<.01
Mechanical ventilation	6336 (54.7%)	5399 (53.1%)	4775 (54.1%)	4330 (54.6%)	.98
Acute kidney injury	6867 (59.3%)	6057 (59.5%)	5264 (59.6%)	4697 (59.2%)	.95
Bleeding during hospitalization	1269 (11.0%)	1069 (10.5%)	954 (10.8%)	914 (11.5%)	.08
Disposition status					.65
Home	3920 (33.9%)	3379 (34.3%)	3010 (34.1%)	2445 (30.8%)	
Facility	3386 (29.2%)	2942 (29.0%)	2595 (29.4%)	2447 (30.8%)	
Death	4175 (36.1%)	3776 (37.2%)	3186 (36.1%)	3011 (37.9%)	

Values are presented as number (percentage) for categorical values and mean (standard error of the mean) for continuous variables. Survey-specific univariate logistic regression and linear regression were used for categorical variables and numeric variables, respectively. The first quartile is the lowest socioeconomic status (SES), while the fourth quartile is the highest SES.

CABG, coronary artery bypass graft; ECMO, extracorporeal membrane oxygenation; IABP, intra-aortic balloon pump; LVAD, left ventricular assist device; MCS, mechanical circulatory support; PCI, percutaneous coronary intervention.

(IABP—5A02110, 5A02210), percutaneous ventricular assist device including Impella/TandemHeart (5A0211D, 5A0221D), extracorporeal membrane oxygenation (ECMO—5A1522, 5A1522F, 5A1522G, 5A1522H), left ventricular assist device (LVAD—02HA3QZ, 02HA0QZ, 02HA4QZ), and heart transplantation (02YA0Z0, 02YA0Z1, 02YA0Z2).[24-26]

The primary outcomes of interest were temporary MCS use (defined as IABP, Impella/TandemHeart, or ECMO) and in-hospital mortality. Secondary outcomes included length of stay, total hospital costs, and disposition.

Statistical methods

All analyses were performed using SAS University Edition, version 9.4 (SAS Institute) and SPSS, version 24 (IBM). For descriptive analyses, we compared baseline patient and hospitalization characteristics between the cohorts. Categorical variables are shown as absolute number and relative frequencies, and continuous variables are presented as mean and standard error of the mean. For comparison, survey-specific univariate logistic regression and linear regression were used for categorical variables and numeric variables, respectively, with SES modeled as an ordinal variable for trends. Multivariable logistic regression analysis was performed to assess the association of SES, patient risk factors, and procedures performed with outcomes. All statistical tests were 2-sided, with $P < .01$ indicating statistical significance; unadjusted P values are shown. Estimated cost for each hospitalization was calculated by merging SID data with cost-to-charge ratio files provided by HCUP. Bing Maps add-in for Microsoft Excel was used to create geographic regional maps.[27]

Results

Patient characteristics

Of 11,003,147 discharge records reviewed in the SID 2016 data set from the aforementioned states, there were 38,520 hospitalizations with CS. Among CS hospitalizations, 30.1% were from regions of the lowest quartile income, 26.4% from the second quartile, 22.9% from the third quartile, and 20.6% from the highest quartile. Baseline characteristics of the study population are listed in Table 1. Patients from areas of higher SES were older (mean age in quartiles 1-4: 65.8, 67.2, 67.5, and 69.4, $P < .01$), more often male, and less likely to be Black or Hispanic. Higher SES regions had a greater proportion of patients covered by either private insurance or Medicare, while Medicaid coverage was more common in lower SES regions.

Overall comorbidity burden was greater for hospitalizations from lower SES regions (frequency of patients with >4 Elixhauser comorbidities in quartiles 1-4: 46.0%, 43.7%, 43.6%, and 40.1%, $P < .01$). There were higher rates of obesity, diabetes mellitus, hyperlipidemia, and renal failure among patients from lower SES regions. However, malignancy and atrial fibrillation were more common in higher SES regions. Despite similar rates of coronary artery disease, prior myocardial infarction, and prior revascularization in all cohorts, hospitalizations from higher SES regions were slightly more likely to present with AMI and CS compared to patients from lower SES regions (frequency of AMI-CS in quartiles 1-4: 41.2%, 43.2%, 43.3%, and 43.0%, $P = .01$).

Interventions for cardiogenic shock and outcomes

Primary outcomes across the cohorts are displayed in Table 2. Overall, in-hospital mortality for the study population was 36.7%. There was no statistically significant difference in mortality across the 4 quartiles (mortality rates from cohorts 1-4: 36.1%, 37.2%, 36.1%, and 37.9%, $P = .05$). In higher SES regions, there was greater overall use of temporary MCS (rates of MCS use in quartiles 1-4: 21.3%, 21.5%, 23.5%, and 24.1%, $P < .01$). Figure 1 displays maps of regional SES and utilization of MCS of 3 representative states, Colorado, Maryland, and New York, which serve as a visualization of the data presented. Considering specific MCS devices, the rates of IABP and ECMO utilization were higher in areas of higher SES, whereas Impella/TandemHeart use was similar in all cohorts. In addition, the rate of vasopressor use was higher in areas of higher SES. Overall rates of the LVAD or heart transplant were very low in all cohorts without significant difference. Bleeding risk is an important consideration when starting MCS; in our study, there were significantly higher rates of bleeding during hospitalization for patients receiving MCS (bleeding rate = 13.6% MCS vs 10.8% no MCS, $P < .01$).

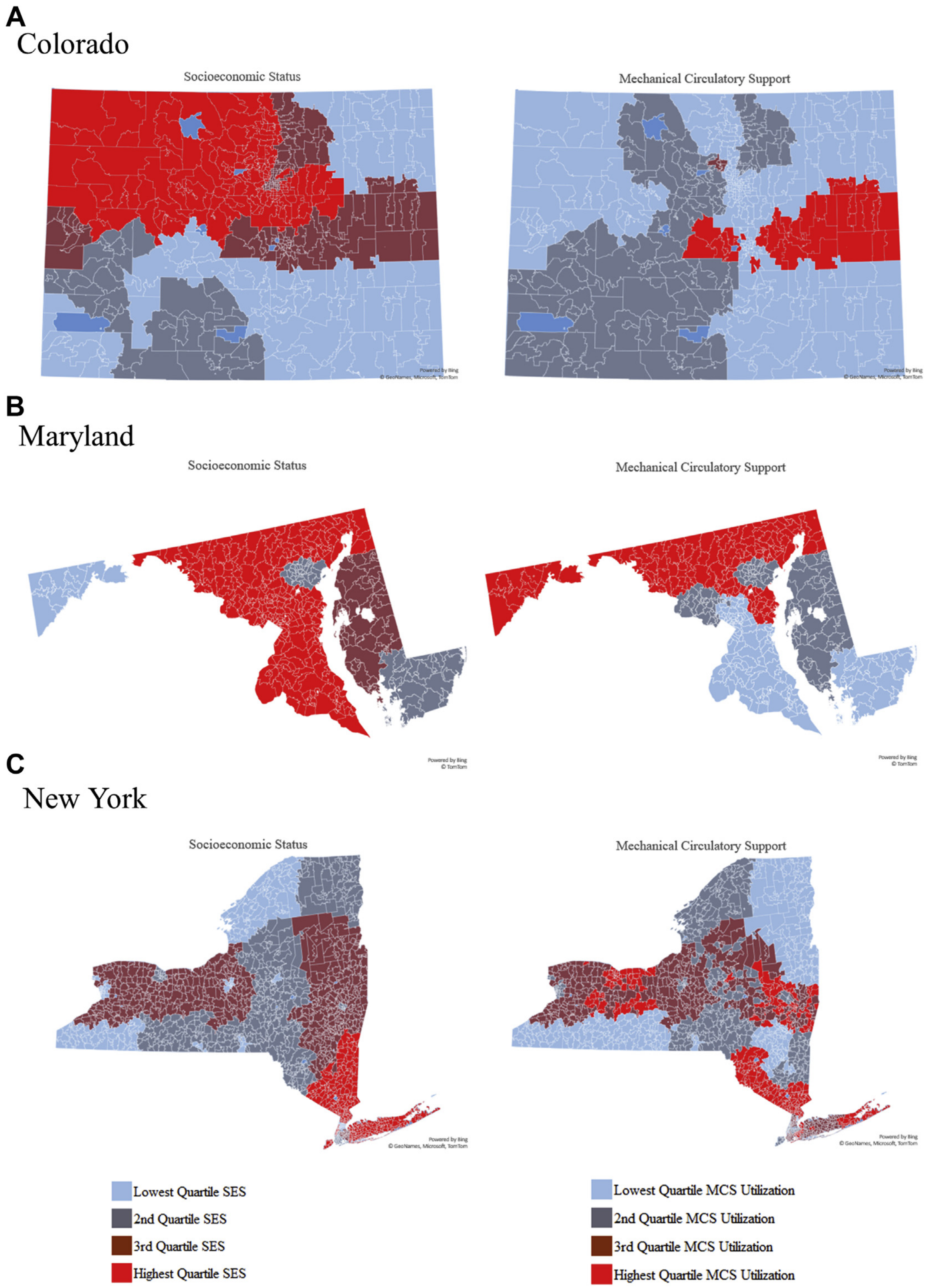
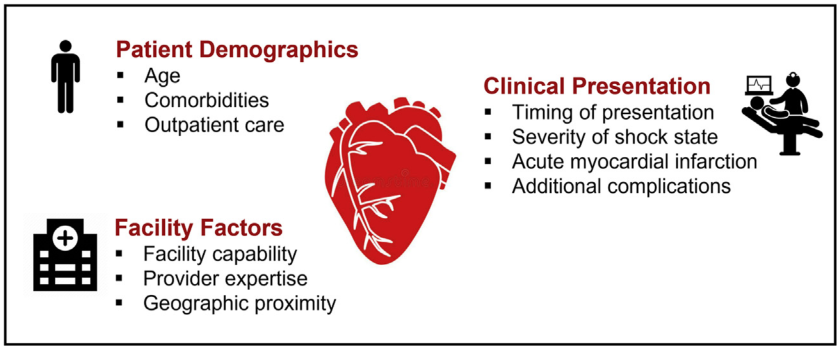


Fig. 1. (**A-C**)—Maps of socioeconomic status and utilization of mechanical circulatory support. Maps of regional income and the use of MCS using Microsoft Excel Bing Maps. Regions are created from the first 3 digits of the zip code. MCS, mechanical circulatory support.

Hospitalizations in the higher SES regions were associated with significantly higher total costs than those in the lower SES regions despite a lack of significant difference in length of stay across the cohorts (mean total cost from cohorts 1-4: $66,446, $70,733, $79,376, and $85,551, $P < .01$). A greater percentage of hospitalizations in the highest SES regions resulted in discharges to other health care facilities.

Outcomes stratified by acute myocardial infarction

Outcomes from the AMI and non-AMI subgroups are shown in Tables 3 and 4, respectively. The proportion of AMI was 42.6% for the overall study population, and hospitalizations from higher SES regions more frequently presented with AMI-CS than those from lower SES regions. Overall, mortality was lower in the AMI subgroup than that in the



Central Illustration. Key factors affecting mechanical circulatory support use in cardiogenic shock.

non-AMI subgroup (37.7% vs 40.3%, $P < .01$). As expected, rates of revascularization were significantly higher in the AMI subgroup than those in the non-AMI subgroup (46.2% vs 8.1%, $P < .01$).

In the AMI subgroup, the rate of PCI was significantly higher in the higher SES cohort (frequency in cohorts 1-4: 38.0%, 38.8%, 41.8%, and 40.1%, $P < .01$). However, there was no difference in the rate of coronary artery bypass grafting. The rate of MCS was higher in regions of higher SES (frequency in cohorts 1-4: 34.6%, 33.1%, 35.3%, and 36.9%, $P < .01$).

In the non-AMI subgroup, rates of revascularization were similar across all cohorts. However, MCS utilization was more frequent in regions of higher SES (frequency in cohorts 1-4: 12.0%, 12.7%, 14.4%, and 14.5%, $P < .01$). Overall, patients with non-AMI-CS had higher rates of receiving multiple MCS devices during hospitalization. In this subgroup, a significantly higher percentage of patients from higher SES regions received heart transplant, and the rate of the LVAD was similar. There was no significant difference in the ratio of durable therapy (LVAD or heart transplant) to temporary MCS across SES cohorts.

Predictors of temporary MCS utilization and mortality with CS

After adjusting for demographics, comorbidities, and admission characteristics, a higher SES quartile was associated with a significantly higher likelihood of MCS use (Table 5, odds ratio [OR] = 1.15, confidence interval [CI] = 1.07-1.23, $P < .01$). Specifically, the highest SES quartile was associated with increased use of ECMO (OR = 1.43, CI = 1.21-1.68), but not with increased use of Impella/Tandem Heart (OR = 1.06, CI = 0.94-1.20). In addition, history of coronary artery disease, presentation with AMI, and revascularization on admission were predictors of MCS utilization, while age over 65 years, liver disease, pulmonary disease, renal disease, and malignancy were all associated with decreased use of MCS. An increased rate of bleeding during hospitalization was associated with MCS use (OR = 1.34, CI = 1.23-1.46).

Table 6 displays predictors of mortality after CS hospitalization. Age over 65 years was one of the most powerful predictors of mortality (OR = 1.58, CI = 1.49-1.68), while presentations with AMI, acute kidney injury, mechanical ventilation, and cardiac arrest were also associated with

Table 3. Association of socioeconomic status and outcomes with cardiogenic shock—acute myocardial infarction subgroup.

	Socioeconomic status quartile				
	First quartile	Second quartile	Third quartile	Fourth quartile	*P*-value
Number of patients	n = 4765	n = 4400	n = 3825	n = 3410	
Mortality	1790 (37.6%)	1655 (37.8%)	1411 (36.9%)	1321 (38.7%)	.54
Length of stay, days	9.9 (0.2)	9.5 (0.2)	9.5 (0.2)	10.2 (0.2)	.39
Total cost, $	65,767 (1107)	66,621 (1154)	74,194 (1319)	79,304 (1619)	.01
Cardiac procedures performed					
PCI	1809 (38.0%)	1707 (38.8%)	1599 (41.8%)	1366 (40.1%)	<.01
CABG	629 (13.2%)	559 (12.7%)	481 (12.6%)	383 (11.5%)	.03
Mechanical circulatory support	1647 (34.6%)	1458 (33.1%)	1349 (35.3%)	1257 (36.9%)	<.01
IABP	1330 (27.9%)	1154 (26.2%)	1085 (28.4%)	990 (29.0%)	.12
Impella/TandemHeart	329 (6.9%)	330 (7.5%)	280 (7.3%)	276 (8.1%)	.07
ECMO	82 (1.7%)	69 (1.6%)	74 (1.9%)	87 (2.6%)	<.01
Single MCS device (% of MCS)	1603 (97.3%)	1415 (97.1%)	1316 (97.6%)	1212 (96.4%)	.34
Multiple MCS devices (% of MCS)	44 (2.7%)	45 (2.9%)	33 (2.4%)	45 (3.6%)	.34
LVAD implantation	27 (0.6%)	23 (0.5%)	14 (0.4%)	14 (0.4%)	.26
Vasopressors used	404 (8.5%)	367 (8.3%)	380 (9.9%)	388 (11.4%)	<.01
Mechanical ventilation	2735 (57.4%)	2431 (55.3%)	2161 (56.5%)	1942 (57.0%)	.85
Acute kidney injury	2606 (54.7%)	2427 (55.2%)	2085 (54.5%)	1884 (55.2%)	.78
Bleeding during hospitalization	570 (12.0%)	463 (10.5%)	421 (11.0%)	381 (11.2%)	.20
Disposition status					.66
Home	1525 (31.1%)	1391 (31.7%)	1257 (32.9%)	1029 (30.1%)	
Facility	1412 (29.7%)	1318 (29.0%)	1138 (29.7%)	1044 (30.6%)	
Death	1790 (37.6%)	1655 (37.8%)	1411 (36.9%)	1321 (38.7%)	

Values are presented as number (percentage) for categorical values and mean (standard error of the mean) for continuous variables.
CABG, coronary artery bypass graft; ECMO, extracorporeal membrane oxygenation; IABP, intra-aortic balloon pump; LVAD, left ventricular assist device; MCS, mechanical circulatory support; PCI, percutaneous coronary intervention.

Table 4. Association of socioeconomic status and outcomes with cardiogenic shock—non–acute myocardial infarction subgroup.

	Socioeconomic status quartile				
	First quartile	Second quartile	Third quartile	Fourth quartile	*P*-value
Number of patients	n = 6813	n = 5776	n = 5004	n = 4527	
Mortality	2385 (35.0%)	2121 (36.8%)	1775 (35.5%)	1690 (37.3%)	.05
Length of stay, days	12.7 (0.2)	12.3 (0.2)	12.7 (0.3)	13.4 (0.3)	.01
Total cost, $	66,6541 (1167)	73,293 (1534)	83,062 (1727)	90,119 (1916)	<.01
Cardiac procedures performed					
PCI	132 (1.9%)	136 (2.4%)	99 (2.0%)	114 (2.5%)	.12
CABG	490 (7.2%)	367 (6.4%)	317 (6.3%)	261 (5.8%)	<.01
Mechanical circulatory support	817 (12.0%)	734 (12.7%)	723 (14.4%)	655 (14.5%)	<.01
IABP	494 (7.3%)	399 (6.9%)	379 (7.6%)	374 (8.3%)	.03
Impella/TandemHeart	130 (1.9%)	132 (2.3%)	120 (2.4%)	92 (2.0%)	.42
ECMO	128 (1.9%)	125 (2.2%)	143 (2.9%)	133 (2.9%)	<.01
Single MCS device (% of MCS)	603 (73.8%)	503 (68.5%)	486 (67.2%)	450 (68.7%)	.02
Multiple MCS devices (% of MCS)	214 (26.2%)	231 (31.5%)	237 (32.8%)	205 (31.3%)	.02
LVAD implantation	169 (2.0%)	165 (2.9%)	145 (2.9%)	120 (2.7%)	.45
Heart transplantation	64 (0.9%)	60 (1.0%)	70 (1.4%)	66 (1.5%)	<.01
Vasopressors used	589 (8.6%)	510 (8.8%)	454 (9.1%)	441 (9.7%)	.05
Mechanical ventilation	3601 (52.9%)	2968 (51.4%)	2613 (52.2%)	2388 (52.8%)	.95
Acute kidney injury	4261 (62.5%)	3630 (62.8%)	3179 (63.5%)	2813 (62.1%)	.97
Bleeding during hospitalization	699 (10.3%)	606 (10.5%)	533 (10.7%)	533 (11.8%)	.04
Disposition status					.85
Home	2395 (35.1%)	2347 (34.5%)	2114 (35.1%)	1416 (31.3%)	
Facility	1974 (29.0%)	1265 (28.2%)	1457 (29.1%)	1403 (31.0%)	
Death	2385 (35.0%)	2121 (36.8%)	1775 (35.5%)	1690 (37.3%)	

Values are presented as number (percentage) for categorical values and mean (standard error of the mean) for continuous variables. Survey-specific univariate logistic regression and linear regression were used for categorical variables and numeric variables, respectively.
CABG, coronary artery bypass graft; ECMO, extracorporeal membrane oxygenation; IABP, intraaortic balloon pump; LVAD, left ventricular assist device; MCS, mechanical circulatory support; PCI, percutaneous coronary intervention.

increased mortality. MCS use was associated with increased risk of mortality in both AMI and non-AMI subgroups, possibly reflecting use in severe shock state. Coronary revascularization, LVAD implantation, and heart transplant were associated with significant improvement in mortality.

Table 5. Independent predictors of temporary mechanical circulatory support use in cardiogenic shock.

Characteristic	Odds ratio	95% confidence interval	*P* value
Demographics			
Median income in zip code, top quartile	1.15	1.07-1.23	<.01
Private payer	1.23	1.14-1.31	<.01
Medicaid	1.13	1.03-1.23	.01
Female sex	0.80	0.76-0.85	<.01
Age >65	0.59	0.55-0.63	<.01
Comorbidities			
Coronary artery disease	1.33	1.25-1.42	<.01
Atrial fibrillation	1.04	0.98-1.11	.09
Depression	0.95	0.86-1.05	.26
Obesity	0.93	0.87-1.00	.05
Diabetes	0.91	0.86-0.97	<.01
Renal failure	0.90	0.85-0.97	<.01
Hypertension	0.87	0.84-0.95	<.01
Liver disease	0.77	0.68-0.89	<.01
Neurological disorders	0.77	0.70-0.84	<.01
Alcohol abuse	0.73	0.65-0.84	<.01
Psychoses	0.72	0.61-0.88	<.01
Chronic pulmonary disease	0.69	0.65-0.74	<.01
Drug abuse	0.67	0.57-0.79	<.01
Malignancy	0.38	0.29-0.51	<.01
Admission characteristics			
PCI performed	4.32	4.01-4.64	<.01
CABG performed	4.03	3.68-4.36	<.01
Acute myocardial infarction	1.63	1.53-1.73	<.01
Bleeding during hospitalization	1.34	1.23-1.46	<.01
Mechanical ventilation	1.32	1.25-1.40	<.01
Acute kidney injury	1.30	1.22-1.38	<.01
Vasopressor use	0.97	0.88-1.06	.48
Cardiac arrest	0.84	0.77-0.91	<.01

CABG, coronary artery bypass graft; PCI, percutaneous coronary intervention.

Discussion

In this large contemporary observational analysis of the SID, we present important findings on the association between SES and MCS device utilization (Central Illustration). First, our data show a higher rate of temporary MCS devices, especially ECMO, in patients residing in regions of higher SES. Second, there was no difference in mortality across SES cohorts, but hospitalizations from higher SES regions resulted in higher total hospital costs. Third, there was no difference in mortality associated with MCS.

Despite advances in coronary revascularization procedures with AMI and technological advancements, mortality associated with CS remains high.[1-3] There are societal and institutional efforts to employ shock initiatives with a protocolized, team-based approach for coordinated care, similar to strategies adapted from other emergent conditions including trauma, out of hospital cardiac arrest, and AMI.[8,13] The National Cardiogenic Shock Initiative and INOVA models demonstrated early registry-based evidence of improvement in outcomes in CS using a strategy to rapidly assess and manage shock state, including targeted therapy with MCS devices.[7-9,12] Prior studies have shown that hospitals with higher CS volumes have lower mortality, potentially alluding to the importance of greater experience and access to immediate care with devices.[28] Although recent data have shown promising results in further improving outcomes at CS centers of excellence, there is a paucity of data in regard to discrepancy in access to these centers.[28-31]

Our study demonstrated a variance of in the frequency of temporary MCS by SES. There were higher rates of temporary MCS in both AMI and non-AMI subgroups in the higher SES quartiles, and this finding persisted when controlling for patient-level and hospital-level variables. Prior publications in CS have shown decreased utilization of temporary MCS in minorities, women, and nonprivately insured patients.[29,32] Socioeconomic disparities have been demonstrated for other advanced surgical procedures, including renal transplant and pancreatic cancer

Table 6. Independent predictors of in-hospital mortality in cardiogenic shock

Characteristic	Odds ratio	95% confidence interval	*P* value
Demographics			
Median income in zip code, top quartile	1.02	0.96-1.08	.46
Age >65	1.58	1.49-1.68	<.01
Female sex	1.13	1.08-1.19	<.01
Medicaid	0.82	0.75-0.89	<.01
Private payer	0.80	0.75-0.86	<.01
Comorbidities			
Malignancy	1.67	1.45-1.97	<.01
Liver disease	1.35	1.23-1.49	<.01
Peripheral vascular disease	1.20	1.14-1.29	<.01
Renal failure	1.05	1.04-1.15	.04
Valvular disease	1.05	0.97-1.15	.30
Hypertension	1.04	0.99-1.09	.09
Diabetes	1.01	0.97-1.07	.65
Congestive heart failure	1.00	0.95-1.07	.92
Coronary artery disease	0.88	0.83-0.92	<.01
Drug abuse	0.87	0.77-0.99	.03
Atrial fibrillation	0.86	0.82-0.91	<.01
Chronic pulmonary disease	0.86	0.82-0.91	<.01
Obesity	0.85	0.79-0.89	<.01
Hyperlipidemia	0.79	0.75-0.83	<.01
Alcohol abuse	0.75	0.68-0.83	<.01
Depression	0.69	0.64-0.76	<.01
Admission characteristics			
Mechanical ventilation	2.81	2.67-2.95	<.01
Cardiac arrest	2.72	2.55-2.90	<.01
Acute myocardial infarction	1.35	1.28-1.42	<.01
Vasopressor use	1.34	1.29-1.45	<.01
Acute kidney injury	1.26	1.20-1.33	<.01
Temporary mechanical circulatory support	1.19	1.11-1.27	<.01
Bleeding during hospitalization	1.14	1.07-1.23	<.01
PCI performed	0.51	0.47-0.55	<.01
LVAD performed	0.30	0.23-0.37	<.01
CABG performed	0.28	0.26-0.30	<.01
Heart transplant performed	0.07	0.04-0.14	<.01

Multivariable comparison of index presentation characteristics and major comorbidities. Table 5 represents predictors of the use mechanical circulatory support. Table 6 represents predictors of mortality. Patient characteristics used for each multivariable analysis are all included in the respective table (5 and 6). CABG, coronary artery bypass graft; LVAD, left ventricular assist device; MCS, mechanical circulatory support; PCI, percutaneous coronary intervention.

resection.[19,20] In acute coronary syndrome, patients residing in lower SES regions have decreased rates of revascularization, and in atrial fibrillation, rates of cardioversion and ablation are lower for the lowest SES quartile.[33,34] Limited outpatient care and management of chronic conditions in lower SES cohorts may have led to decreased baseline functional status, in turn deterring the use of temporary MCS in our study. This theory is supported by our finding that patients in the lower SES quartiles had higher baseline comorbidities at the time of hospitalization with CS. Pervasive differences in access to preventative care in America lead to discrepant overall cardiovascular health.[35] Despite recent campaigns to promote equality, lower-income communities often have difficulty obtaining tools that promote healthy lifestyles.[36,37] It is also possible that patients from regions of lower SES may have delayed presentation of CS, resulting in less reversible condition limiting the use of MCS. In AMI, prior studies show a trend toward increased time from the symptom onset to reperfusion in lower SES cohorts.[38] Another potential reason for reduced MCS use is that patients from lower SES regions may be less likely to be admitted to CS centers of excellence. In the AMI subgroup, patients from lower SES regions had lower rates of PCI, possibly implying fewer were admitted to PCI-capable centers.

We found no difference in mortality attributable to SES despite a small difference in the use of temporary MCS. Our study predates recent efforts geared toward implementing shock initiatives, which may partially explain the lack of benefit with MCS use. Furthermore, a wide spectrum of CS at the time of initial presentation and the inability to elucidate the stages of CS with administrative database may explain this finding in our study.[10] There is a lack of randomized data studying MCS, and the relation may be confounded by selection bias with increasing MCS use in more severe shock states. Nevertheless, temporary MCS devices including IABP, Impella/TandemHeart, and ECMO have become an important part of modern CS management.[14-16] Recent studies show that hemodynamic monitoring coupled with early MCS usage compared to delayed employment leads to improved outcomes, implying an evolving role of targeted MCS.[39,40] Classification systems such as the Society for Cardiology Angiography and Interventions Expert Consensus help with early identification and stratification of CS, with algorithms assisting in appropriate choice of MCS.[41] Our 2016 SID population has lower overall mortality than prior studies, possibly reflecting higher rates of CS type A and B in the study.

Temporary MCS is increasingly being used as a bridge to destination therapy, including the LVAD and heart transplant. In our study, the ratio of lifesaving durable therapy to temporary MCS was similar across SES cohorts, implying a comparable allocation of durable therapy by SES. The American Heart Association recommends using targeted MCS in CS to maintain cardiac output and adequate hemodynamics and highlights its role as a bridge to durable therapy.[13] The volume of LVAD procedures has increased over time, offering a more sustainable approach for end-stage patients.[42] CS outcomes have been shown to be improved at LVAD-capable centers, especially in non-AMI CS.[43] As more centers of excellence for CS develop, it is important to have equitable access to potential lifesaving therapies.

Several limitations of the current analysis should be discussed. First, the SID database is generated using ICD-10-CM codes for diagnoses and procedures, used for identification of CS, AMI, and MCS procedures. However, HCUP quality-control measures are routinely performed to confirm data validity and reliability.[22] Second, we utilized SID data from 9 states that are regionally and socioeconomically diverse and statistically large enough to generate a representative sample of the United States, but we recognize the limitations in generalizability. Third, we use regional income of residency as a proxy for SES, which may not accurately represent individual income. There is opportunity for future studies to further investigate the impact of individual income on CS outcomes. Fourth, the SID lacks key information including medications, CS severity, timing of presentation, hemodynamic parameters, cardiac biomarkers, left ventricular ejection fraction, laboratory values, and frailty. Fifth, the SID contains only inpatient data and does not include information on long-term outcomes or survival. This study does not contain specific hospital characteristics including location, regional demographics, or interhospital transfers, which would be interesting to investigate in future study. Despite these limitations, the large contemporary SID sample of CS hospitalizations enables study of the impact of SES on management of CS.

Conclusion

In conclusion, there is increased use of temporary MCS in CS for patients from regions of higher SES. We found no significant mortality difference across SES cohorts. There was no difference in mortality associated with MCS use. However, given the evolving role of MCS in management of CS, equitable access is an important consideration.

Declarations of competing interests

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Ethics statement

Institutional review board approval and informed consent were not required because all data collection was obtained from a deidentified administrative database.

Supplementary material

To access the supplementary material accompanying this article, visit the online version of the *Journal of the Society for Cardiovascular Angiography & Interventions* at 10.1016/j.jscai.2022.100027.

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