ORIGINAL RESEARCH

Association of Neighborhood Race and Income With Survival After Out-of-Hospital Cardiac Arrest

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Background—For individuals with an out-of-hospital cardiac arrest (OHCA), survival may be influenced by the neighborhood in which the arrest occurs.

Methods and Results—Within the national CARES (Cardiac Arrest Registry to Enhance Survival) registry, we identified 169 502 patients with OHCA from 2013 to 2017. On the basis of census tract data, OHCAs were categorized as occurring in predominantly white (>80% white), majority black (>50% black), or integrated (neither of these 2) neighborhoods and in low-income (median household <$40 000), middle-income ($40 000 to $80 000), or high-income (>$80 000) neighborhoods. With hierarchical logistic regression, the association of neighborhood race and income on overall survival was assessed. Overall, 37.5%, 16.6%, and 45.9% of people had an OHCA in predominantly white, majority black, and integrated neighborhoods, and 30.1%, 53.4%, and 16.5% in low-, middle-, and high-income neighborhoods, respectively. Compared with OHCAs occurring in predominantly white neighborhoods, those in majority black neighborhoods were 12% less likely (6.9% versus 10.6%; adjusted odds ratio 0.88; 95% CI 0.82-0.95; $P<0.001$) to survive to discharge, whereas those in integrated neighborhoods had similar survival (10.3% versus 10.6%; adjusted odds ratio 1.00; 95% CI 0.96-1.04; $P=0.93$). Compared with high-income neighborhoods, those in middle-income neighborhoods were 11% (10.1% versus 11.3%; adjusted odds ratio 0.89; 95% CI 0.8-0.94; $P<0.001$) less likely to survive to discharge, whereas those in low-income neighborhoods were 12% (8.6% versus 11.3%; adjusted odds ratio 95% CI 0.83-0.94; $P<0.001$) less likely to survive. Differential rates of bystander cardiopulmonary resuscitation only modestly attenuated neighborhood differences in survival.

Conclusions—OHCAs in majority black and non–high-income neighborhoods have lower survival rates, and these differences were not explained by differential bystander cardiopulmonary resuscitation rates. **(*J Am Heart Assoc*. 2020;9:e014178. DOI: 10.1161/JAHA.119.014178.)**

Key Words: cardiac arrest • income • race • survival

Out-of-hospital cardiac arrest affects ≈350 000 individuals annually in the United States and is a major public health condition.[1] Although survival rates are low (<10%),[2] there is substantial variation across communities, with more than a 5-fold difference (3% to 16%) in 1 multicenter registry.[3] The influence of neighborhood factors, especially race and income, on one's likelihood of surviving an out-of-hospital cardiac arrest, however, is less clear. Further elucidating potential disparities in survival between communities with different racial and income compositions may guide public health strategies to improve bystander education, emergency medical service (EMS) response, and hospital care.

Prior studies of neighborhood effects on out-of-hospital cardiac arrest outcomes have been limited but suggest that neighborhood race and socioeconomic status may be important determinants.[4–9] One prior study reported substantially lower rates of bystander cardiopulmonary resuscitation (CPR) in communities that were largely black or low-income communities, but did not examine neighborhood effects on rates of survival.[4] A more recent study from the Resuscitation Outcomes Consortium reported lower rates of bystander CPR, survival to discharge, and other survival outcomes in largely black communities, but neighborhood-level differences in survival were eliminated after accounting for the fact that most of the black neighborhoods were clustered in 4 of the 10 registry sites.[5] Thus, the evidence that neighborhood race has an effect on OHCA survival is limited. Other studies have examined the effect of neighborhood socioeconomic or

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Accompanying Tables S1 through S5 are available at https://www.ahajournals.org/doi/suppl/10.1161/JAHA.119.014178

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Received August 2, 2019; accepted December 12, 2019.

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Clinical Perspective

What Is New?

- Patients with an out-of-hospital cardiac arrest in majority black and non–high-income neighborhoods have lower overall survival rates, and survival differences are not explained by neighborhood differences in bystander CPR rates.
- Although there were differences in overall survival by neighborhood race and income, survival rates to hospital admission were generally similar across neighborhoods.

What Are the Clinical Implications?

- Differences in other aspects of emergency medical service response that differ by neighborhood race and income may be important to address in order to reduce out-of-hospital cardiac arrest survival disparities.
- The lack of neighborhood differences in rates of survival to hospital admission implies that overall survival differences may also be due to differences in postresuscitation care at hospitals.
- Our findings suggest the need to improve not only bystander CPR rates but also other aspects of emergency medical service treatment and postresuscitation care in communities that are majority black and non–high income.

deprivation indices and reported worse survival outcomes among patients with OHCAs in poorer neighborhoods.[6-9] These studies, however, used different composite socioeconomic indices that may not be readily accessible to policy makers unlike neighborhood income level, which can be readily obtained. Moreover, the likelihood of surviving an out-of-hospital cardiac arrest in a low-, middle-, or high-income neighborhood independent of the racial composition of the neighborhood has also not been well characterized in prior studies but is important to understand to better define which types of communities cardiac arrest interventions should be targeted to reduce disparities in survival.

Accordingly, we leveraged data from CARES (the Cardiac Arrest Registry to Enhance Survival), which collects cardiac arrest data from a broad catchment area of more than 120 million US residents. We investigated differences in rates of survival to discharge and favorable neurological survival among predominantly white, integrated, and majority black neighborhoods as well as among low-, middle-, and high-income neighborhoods. If survival differences by neighborhood race or income were present, we examined the extent to which survival differences were due to neighborhood differences in rates of bystander CPR and whether these differences were evident at the time of hospital admission. By better understanding these associations, we sought to determine to what extent out-of-hospital cardiac arrest survival differences by neighborhood race or income were largely due to care occurring outside the hospital.

Methods

The data that support the findings of this study are available from the corresponding author on request and approval by the CARES registry.

Data Sources and Study Design

CARES is a prospective, multicenter registry of patients with out-of-hospital cardiac arrest in the United States. Established by the Centers for Disease Control and Emory University for public health surveillance and continuous quality improvement, the design of the registry has been previously described.[10,11] Briefly, all patients with a confirmed out-of-hospital cardiac arrest (defined as pulselessness, apnea, and unresponsiveness) and for whom resuscitation is attempted are identified and followed from over 1400 EMS systems, representing a catchment area of ≈120 million US residents. Data are collected from 3 sources that, collectively, define the continuum of emergency cardiac care: 911 dispatch centers, EMS agencies, and receiving hospitals. Standardized international Utstein definitions for defining clinical variables and outcomes are used to ensure uniformity.[12] A CARES analyst reviews every record for completeness and accuracy.[11] The study was approved by Saint Luke's Mid America Heart Institute, which waived the requirement for informed consent because the analysis included only deidentified data.

Study Population

A total of 266 592 adults 18 years of age or older met criteria for an out-of-hospital cardiac arrest between January 1, 2013 and December 31, 2017 (Figure 1). We excluded 42 046 events that occurred in a residential healthcare facility because these sites typically have on-site healthcare professionals. We further excluded 29 012 events that were witnessed by EMS personnel, 6592 events due to drowning, and 561 events with missing survival data. Additionally, we excluded 1732 events for which we were unable to link patients to a US census tract, yielding 186 649 out-of-hospital cardiac arrest events. We then excluded 17 147 events from 6875 census tracts with fewer than 5 total events during the study period. Our final cohort comprised 169 502 patients with an out-of-hospital cardiac arrest from 14 817 US census tracts.

Data Collection and Processing

CARES collects patient-level data on demographics (age, sex, and race), location of cardiac arrest, initial cardiac arrest

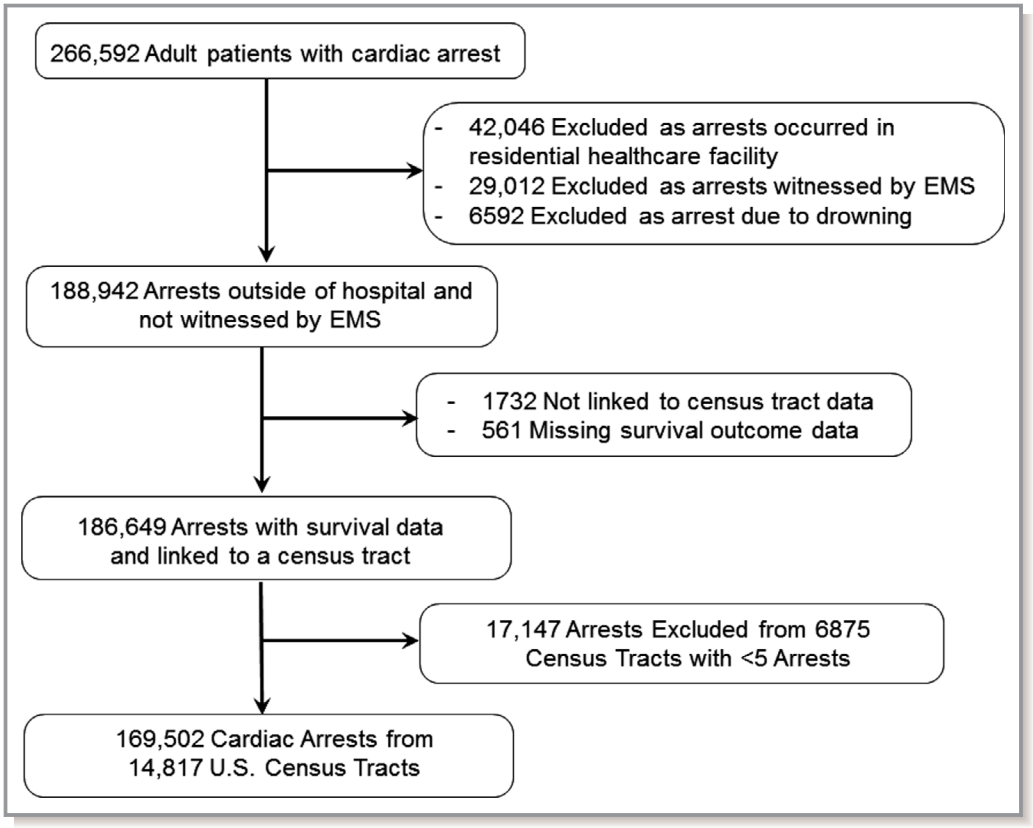

Figure 1. Definition of the study cohort. EMS indicates emergency medical services.

rhythm, and whether the arrest was witnessed. Additionally, information is gathered as to whether bystander CPR was administered before EMS arrival and cardiac arrest etiology (presumed cardiac, respiratory, and other) is collected, as well as times to EMS arrival and duration of EMS treatment.

Survival outcomes were also collected by CARES. Our primary outcome was survival to hospital discharge. Secondary outcomes included survival to hospital admission and favorable neurological survival. Survival to hospital admission was defined as having return of spontaneous circulation prior to hospital arrival. Favorable neurological survival was defined as survival to hospital discharge with a cerebral performance category score of 1 (mild to no neurological disability) or 2 (moderate neurological disability).[13] In addition, we examined rates of bystander CPR.

To obtain information on neighborhood race and income on each patient, CARES data were geocoded to a US census tract by the Centers for Disease Control on the basis of the address of the cardiac arrest. Census tracts are used as proxies for neighborhoods as they typically represent economically and socially homogeneous groups of ≈1200 to 8000 residents.[14] Neighborhood variables were linked to each geocoded address with data from the 2010 US Census Summary Files and the 2016 American Community Survey's 5-year estimates. From this linkage, the racial and income composition of each census tract neighborhood were identified. Categories of neighborhood race and income were defined a priori and were classified as predominantly white (>80% white), majority black (>50% black), or integrated. Integrated neighborhoods were those that met neither criterion for predominantly white or majority black. These cut points were chosen for interpretability but also mirrored the racial distribution in the study, as 19.3% of the neighborhoods were >50% black and 50% were >77.5% white. We likewise classified neighborhoods as low (median household income < $40 000), middle ($40 000 to $80 000), or high income (> $80 000), which also mirrored the distribution of the census tracts (lower quartile: ≤$40 716; middle 2 quartiles: $40 717 to $77 177; upper quartile: ≥$77 178). Additionally, we evaluated neighborhood race and income as continuous variables.

Statistical Analyses

The primary outcome was survival to hospital discharge. Baseline differences between those who survived to hospital discharge and those who died were compared using t tests for continuous variables and the χ^2 test for categorical variables.

To assess that our categories for neighborhood race and income were robust, we first evaluated the relationship between neighborhood race and income with survival to discharge as continuous variables with a test of trend.

Neighborhood race was categorized by deciles of proportion of black inhabitants, and neighborhood income was categorized by increments of $10 000 in median household family income. Then, to determine the association of neighborhood-level race and income with survival, we constructed a hierarchical logistic regression model in which patient characteristics as well as neighborhood race and income were all modeled together as fixed effects, and the census tract neighborhood as a random effect, to address clustering of patients within neighborhoods. Neighborhood race (predominantly white, integrated, and majority black) and income (low, middle, and high) were categorized as previously outlined, and patient factors included patient age, sex, and race, whether the arrest was witnessed, location of cardiac arrest, and initial cardiac arrest rhythm. All covariates were retained in the model regardless of statistical significance. To determine whether differences in survival to discharge were mediated by differential rates of bystander CPR by neighborhood race, or income,[4] we evaluated whether additional adjustment for bystander CPR attenuated survival differences. If survival differences remained, we explored whether this could be explained by differential EMS arrival times (time from activation to arrival of EMS) and treatment times (time from EMS arrival to departure) by neighborhood race and income by further including these variables in the model. Additionally, because rates of witnessed or shockable out-of-hospital cardiac arrest may differ by neighborhood, we repeated the above analyses in these patient subgroups.

Similar hierarchical regression models were constructed for the secondary end points of bystander CPR, survival to hospital admission, and favorable neurological survival at discharge. Discharge cerebral performance category scores were missing in 350 patients (0.2% of cohort). We used multiple imputation methods to impute missing values on the basis of all other observed data. Imputations were performed with Markov Chain Monte Carlo methods as implemented in SAS PROC MI (SAS Institute, Cary, NC). Ten imputed data sets were generated; analyses were replicated across data sets and pooled to obtain final estimates. Results with and without imputation were very similar; only the former are presented.

For each analysis, the null hypothesis was evaluated at a 2-sided significance level of 0.05, and 95% CIs were calculated using robust standard errors. All statistical analyses were conducted using SAS Version 9.1.3 (SAS Institute, Cary, NC) and R Version 2.6.0 (Free Software Foundation, Boston, MA).

Results

Characteristics of the study cohort of 169 502 patients with out-of-hospital cardiac arrest are summarized in Table 1. The mean age of the study population was 62.8 years (SD 16.7 years), 63.3% were men, and 21.0% were of black race. Overall, 37.5% had had a cardiac arrest in a predominantly white neighborhood, 16.6% in a majority black neighborhood, and 45.9% in an integrated neighborhood, whereas 30.1%, 53.4%, and 16.5% had had cardiac arrests in low-, middle-, and high-income neighborhoods, respectively. A total of 16 740 (9.9%) patients survived to hospital discharge. Patients of female sex and black race were less likely to survive to hospital discharge, whereas patients with a witnessed arrest, an arrest in a public location, bystander CPR, and an initial shockable cardiac arrest rhythm were more likely to survive to discharge.

Study Outcomes

When assessed as continuous variables, both neighborhood race (P for trend <0.001) and neighborhood income (P for trend of 0.048) were each associated with the likelihood of a patient surviving to discharge after an out-of-hospital cardiac arrest (Figure 2). Unadjusted rates of survival to discharge by the study categories of neighborhood race and income are shown in Figure 3. Survival rates were similar for arrests in predominantly white and integrated neighborhoods but were lower in majority black neighborhoods. There was a gradient of lower survival in middle- and low-income neighborhoods as compared with high-income neighborhoods. After multivariable adjustment, patients with an out-of-hospital cardiac arrest in a majority black neighborhood were 12% less likely (adjusted odds ratio [OR] 0.88; 95% CI 0.82-0.95; P<0.001) to survive to discharge as compared with those in a predominantly white neighborhood, whereas there was no difference in survival between integrated and predominantly white neighborhoods (Table 2). As compared with high-income neighborhoods, those in middle-income neighborhoods were 11% (adjusted OR 0.89; 95% CI 0.85-0.94; P<0.001) less likely to survive to discharge, whereas those in low-income neighborhoods were 12% (adjusted OR 0.88; 95% CI 0.83-0.94; P<0.001) less likely to survive. Adjusted estimates for different combinations of neighborhood race and income strata are provided in Table 3. Notably, lower rates of survival to discharge in black patients (no adjustment for neighborhood factors: adjusted OR for black versus white patients 0.86; 95% CI 0.82-0.91; P>0.001) were markedly attenuated after adjustment for neighborhood race and income (adjusted OR for black versus white patients 0.95; 95% CI 0.89-1.02; P=0.19). The full model is summarized in Table S1.

Rates of bystander CPR differed markedly by neighborhood factors. After adjustment for patient and cardiac arrest characteristics, patients in majority black and integrated neighborhoods were respectively 40% and 12% less likely to have CPR initiated by a bystander as compared with patients in predominantly white neighborhoods (see Table 2). Similarly, those in low- and middle-income neighborhoods were 33% and 12% less likely to receive bystander CPR as

Table 1. Baseline Characteristics of Cohort, by Survival to Discharge

Variables	Total N=169 502	Survived to Discharge n=16 740	Died n=152 762	*P* Value
Patient factors				
Age, y				<0.001
Mean±SD	62.8±16.7	58.0±15.4	63.3±16.7	
Median (interquartile range)	63.0 (52.0, 75.0)	59.0 (49.0, 68.0)	64.0 (53.0, 76.0)	
Sex				<0.001
Male	107 355 (63.3%)	11 506 (68.7%)	95 849 (62.7%)	
Female	62 136 (36.7%)	5234 (31.3%)	56 902 (37.3%)	
Missing	11		11	
Patient-level race and ethnicity				<0.001
White	78 850 (46.5%)	8398 (50.2%)	70 452 (46.1%)	
Black	35 632 (21.0%)	2777 (16.6%)	32 855 (21.5%)	
Asian	3419 (2.0%)	306 (1.8%)	3113 (2.0%)	
Hispanic	9580 (5.7%)	850 (5.1%)	8730 (5.7%)	
Native Hawaiian or Pacific Islander	900 (0.5%)	61 (0.4%)	839 (0.5%)	
American Indian or Alaskan Native	776 (0.5%)	60 (0.4%)	716 (0.5%)	
Unknown	40 279 (23.8%)	4287 (25.6%)	35 992 (23.6%)	
Missing	66	1	65	
Location of cardiac arrest				<0.001
Home	139 937 (82.6%)	10 361 (61.9%)	129 576 (84.8%)	
Public or commercial building	14 377 (8.5%)	3336 (19.9%)	11 041 (7.2%)	
Public street or highway	10 473 (6.2%)	1668 (10.0%)	8805 (5.8%)	
Recreational facility	2797 (1.7%)	971 (5.8%)	1826 (1.2%)	
Industrial place	965 (0.6%)	245 (1.5%)	720 (0.5%)	
Other	953 (0.6%)	159 (0.9%)	794 (0.5%)	
Was cardiac arrest witnessed				<0.001
Bystander witnessed	74 871 (44.2%)	12 158 (72.6%)	62 713 (41.1%)	
Unwitnessed	94 631 (55.8%)	4582 (27.4%)	90 049 (58.9%)	
Cardiac arrest etiology				<0.001
Presumed cardiac etiology	150 791 (89.0%)	14 487 (86.5%)	136 304 (89.2%)	
Respiratory	11 215 (6.6%)	1310 (7.8%)	9905 (6.5%)	
Other	7496 (4.4%)	943 (5.6%)	6553 (4.3%)	
Person initiating CPR				<0.001
First responder	56 678 (33.4%)	4363 (26.1%)	52 315 (34.2%)	
Responding EMS personnel	47 574 (28.1%)	3363 (20.1%)	44 211 (28.9%)	
Family member	36 034 (21.3%)	3703 (22.1%)	32 331 (21.2%)	
Lay person	23 665 (14.0%)	4342 (25.9%)	19 323 (12.6%)	
Lay medical provider	5502 (3.2%)	960 (5.7%)	4542 (3.0%)	
Other	45 (0.0%)	9 (0.1%)	36 (0.0%)	
Missing	4		4	
Bystander CPR	65 201 (38.5%)	9005 (53.8%)	56 196 (36.8%)	

Continued

Table 1. Continued

Variables	Total N=169 502	Survived to Discharge n=16 740	Died n=152 762	*P* Value
First cardiac arrest rhythm				<0.001
Nonshockable				
Asystole	83 861 (49.5%)	1690 (10.1%)	82 171 (53.8%)	
PEA	30 190 (17.8%)	2530 (15.1%)	27 660 (18.1%)	
Unknown nonshockable rhythm	18 281 (10.8%)	2120 (12.7%)	16 161 (10.6%)	
Shockable				
Ventricular fibrillation	26 697 (15.8%)	7044 (42.1%)	19 653 (12.9%)	
Ventricular tachycardia	1545 (0.9%)	457 (2.7%)	1088 (0.7%)	
Unknown shockable rhythm	8918 (5.3%)	2895 (17.3%)	6023 (3.9%)	
Missing	10	4	6	
Neighborhood factors				
Race of census tract				<0.001
≥80% White	63 501 (37.5%)	6749 (40.3%)	56 752 (37.2%)	
≥50% Black	28 144 (16.6%)	1946 (11.6%)	26 198 (17.1%)	
Integrated	77 857 (45.9%)	8045 (48.1%)	69 812 (45.7%)	
Median household income of census tract				<0.001
<$40 000 annually	51 087 (30.1%)	4416 (26.4%)	46 671 (30.6%)	
$40 000 to $80 000 annually	90 480 (53.4%)	9179 (54.8%)	81 301 (53.2%)	
>$80 000 annually	27 935 (16.5%)	3145 (18.8%)	24 790 (16.2%)	

CPR indicates cardiopulmonary resuscitation; EMS, emergency medical services; PEA, pulseless electrical activity.

compared with those in high-income neighborhoods. However, inclusion of bystander CPR as a patient-level variable in the model for survival to discharge did not substantially attenuate survival differences between predominantly white and majority black neighborhoods nor between high- and middle- or low-income neighborhoods (see Table 2).

There were small differences by neighborhood race and income in EMS arrival times. In contrast, EMS treatment times were longer in predominantly white neighborhoods (median of 23.4, 19.7, and 21.0 minutes [P<0.001] in predominantly white, majority black, and integrated neighborhoods, respectively) and high-income neighborhoods (median of 22.8, 22.0, and 21.0 minutes [P<0.001] in high-, middle-, and low-income neighborhoods, respectively) (Table S2). Nonetheless, additional adjustment for EMS arrival and treatment times among those patients with complete data on EMS times did not significantly attenuate survival differences by neighborhood race or income (Table S3).

Rates of favorable neurological discharge mirrored those for survival to discharge (see Figure 3 and Table 2). Patients with an out-of-hospital cardiac arrest in a majority black neighborhood were 24% less likely to survive without severe neurological disability as compared with predominantly white communities, whereas there was no difference between integrated and predominantly white neighborhoods. Rates of favorable neurological discharge were also lower in middle- and low-income neighborhoods as compared with high-income neighborhoods. As with the outcome of survival to discharge, these differences by neighborhood race and income were only modestly attenuated after neighborhood differences in rates of bystander CPR had been accounted for (see Table 2).

Despite differences by neighborhood race and income in overall survival and favorable neurological discharge, rates of survival to hospital admission were not different between out-of-hospital cardiac arrest patients from predominantly white and majority black neighborhoods and from high-income and low-income neighborhoods. Moreover, there were only small differences in rates of survival to hospital admission between high-income and medium-income neighborhoods, and rates of survival to hospital admission were actually higher in integrated neighborhoods as compared with predominantly white neighborhoods (see Table 2). Finally, all study findings were similar when the analyses were restricted to the 74 871 (44.2%) out-of-hospital cardiac arrests that were witnessed by a bystander or to the 37 160 (21.9%) patients with an initial shockable cardiac arrest rhythm (Tables S4 and S5).

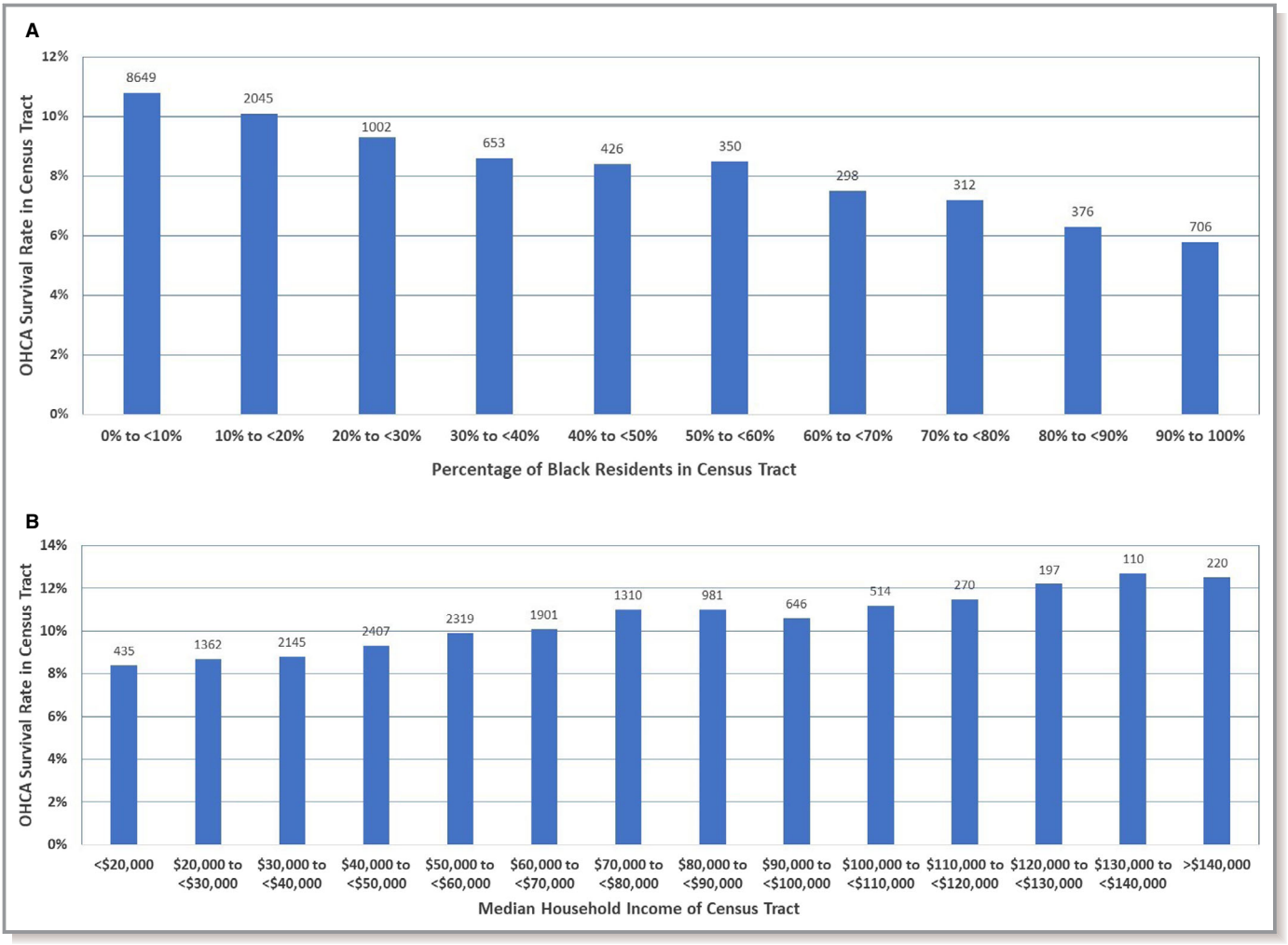

Figure 2. Neighborhood race and income for survival to discharge. Tests of trend of the relationship between neighborhood race (**A**) and income (**B**) and survival to discharge are shown. Numbers above each vertical bar represent number of US census tracts. OHCA indicates out-of-hospital cardiac arrest.

Discussion

We found that the racial composition and median income of a neighborhood influences the likelihood that an individual with an out-of-hospital cardiac arrest survives to hospital discharge or has favorable neurological survival. Patients with an out-of-hospital cardiac arrest in a majority black neighborhood were 12% less likely to survive to discharge and 24% less likely to survive without severe neurological disability than those in a predominantly white neighborhood, whereas there were no differences in either outcome between integrated and predominantly white neighborhoods. In contrast, rates of survival to discharge and favorable neurological survival were both lower in low- and middle-income neighborhoods as compared with high-income neighborhoods. Importantly, similar patterns were found in the population with a witnessed out-of-hospital cardiac arrest, suggesting that survival differences were not simply due to differences in witnessed cardiac arrest events by neighborhood race or income, as witnessed events typically are the opportunities to provide bystander CPR.

Few studies have evaluated the effect of neighborhood race on out-of-hospital cardiac arrest outcomes. One early study in CARES found lower rates of bystander CPR in communities that were largely black or low income but did not examine survival, as it was likely underpowered given a sample size of 14 225 patients in that study (or <9% of the current cohort).[4] A more recent study of 22 816 out-of-hospital cardiac arrests from the Resuscitation Outcome Consortium reported much lower odds of survival to discharge in largely black communities than were found in this study (ORs of 0.65 and 0.68 for communities that were >75% black and 51% to 75% black, as compared with those that were <25% black), but the larger relative differences may have been due to the limited geographical regions examined in that study.[5] Our findings extend the findings of these 2 prior studies in a much larger cohort of patients with out-of-hospital

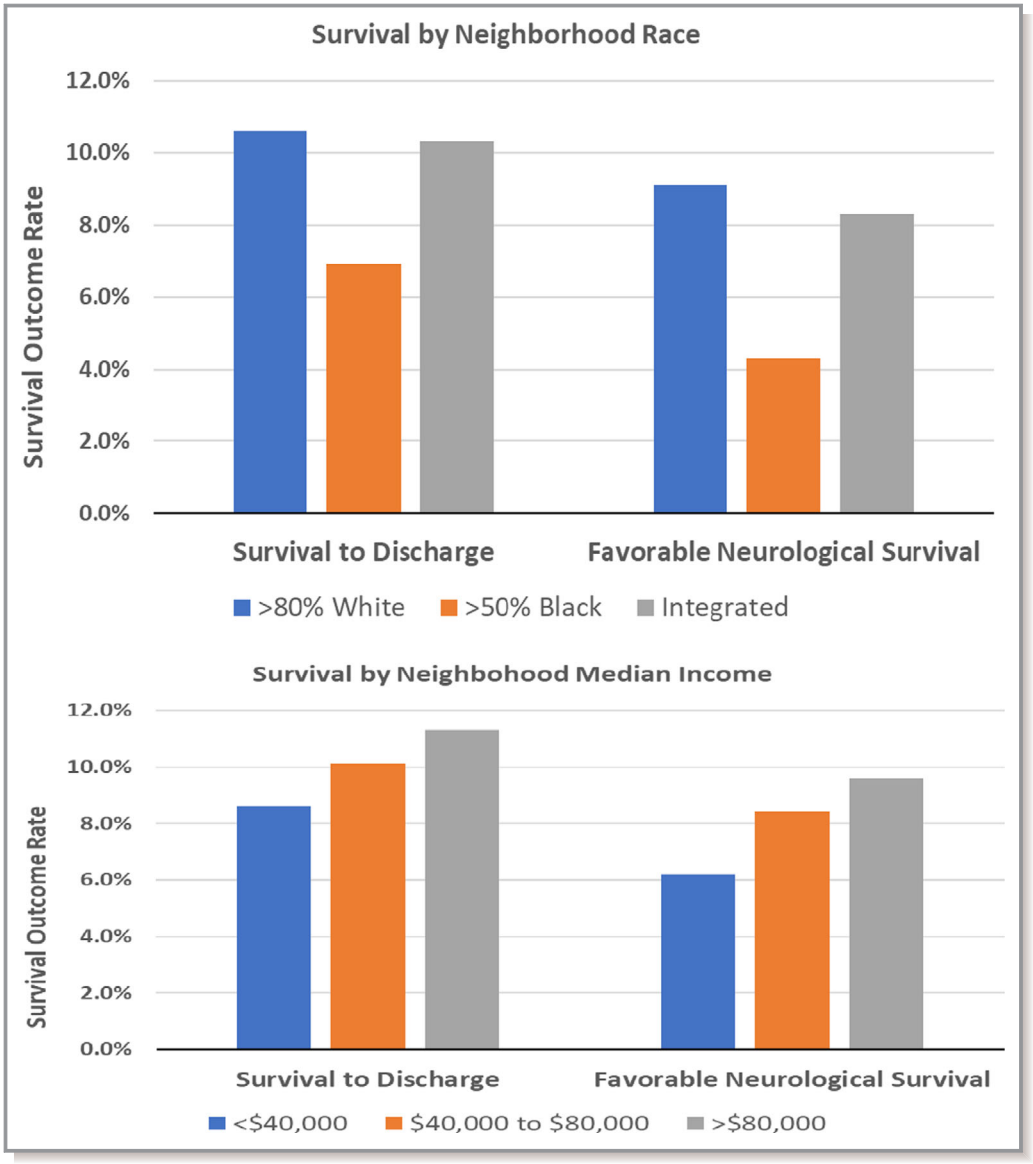

Figure 3. Unadjusted rates of survival outcomes by categories of neighborhood race and income.

cardiac arrest and in a catchment area representing approximately one third of the United States. We confirmed differences in survSival in largely black neighborhoods but found no survival differences in patients from integrated neighborhoods. Moreover, we provided explicit reporting on the effect of the median income of a neighborhood on several survival outcomes for out-of-hospital cardiac arrest, which has been reported largely for the outcome of receipt of bystander CPR.[15] Although studies on the effect of composite neighborhood socioeconomic indices on OHCA outcomes exist,[6-9] these composite indices may not be as readily accessible as neighborhood income.

Our findings suggest important deficiencies in our current public health approach in responding to out-of-hospital cardiac arrest. Low survival rates for this condition are unsurprising, but potential disparities in survival based solely on the racial and income composition of the neighborhood in which one has a cardiac arrest raise concerns. Although differences in CPR training[16] and bystander CPR delivery[4,5] have been reported by neighborhood race and income, we found that these differences accounted for only a small fraction of the overall survival differences between majority black and predominantly white neighborhoods and between low- and middle-income versus high-income neighborhoods. Other reasons for survival differences by neighborhood may be related to differences in EMS treatment, and we found substantially longer EMS treatment times in predominantly white and high-income neighborhoods than in their counterpart comparisons. However, additional adjustment for EMS arrival and treatment times did not attenuate survival

Table 2. Association Between Neighborhood Race and Income and Survival Outcomes

Outcome	Neighborhood Race						
	>80% White* (n=63 501)	>50% Black (n=28 144)	Adjusted OR (95% CI)	*P* Value	Integrated (n=77 857)	Adjusted OR (95% CI)	*P* Value
Primary outcome							
Survival to hospital discharge	6749 (10.6%)	1946 (6.9%)	0.88 (0.82, 0.95)	<0.001	8045 (10.3%)	1.00 (0.96, 1.04)	0.93
Adjusted for bystander CPR			0.91 (0.84, 0.98)	0.009		1.01 (0.97, 1.05)	0.77
Secondary outcomes							
Bystander CPR	27 764 (43.7%)	6962 (24.7%)	0.60 (0.57, 0.63)	<0.001	30 475 (39.1%)	0.88 (0.85, 0.91)	<0.001
Survival to hospital admission	17 470 (27.5%)	6478 (23.0%)	0.98 (0.93, 1.03)	0.34	22 603 (29.0%)	1.11 (1.08 1.14)	<0.001
Favorable neurological discharge	5792 (9.1%)	1203 (4.3%)	0.76 (0.70, 0.83)	<0.001	6457 (8.3%)	0.97 (0.92, 1.01)	0.14
Adjusted for bystander CPR			0.79 (0.72, 0.80)	<0.001		0.97 (0.93, 1.02)	0.25
	Neighborhood Income						
	>$80 000* (n=27 935)	<$40 000 (n=51 087)	Adjusted OR (95% CI)	*P* Value	$40 000 to $80 000 (n=90 480)	Adjusted OR (95% CI)	*P* Value
Primary outcome							
Survival to hospital discharge	3145 (11.3%)	4416 (8.6%)	0.88 (0.83, 0.94)	<0.001	9179 (10.1%)	0.89 (0.85, 0.94)	<0.001
Adjusted for bystander CPR			0.90 (0.85, 0.96)	0.001		0.90 (0.86, 0.95)	<0.001
Secondary outcomes							
Bystander CPR	12 448 (44.6%)	15 496 (30.3%)	0.67 (0.64, 0.70)	<0.001	37 257 (41.2%)	0.88 (0.85, 0.92)	<0.001
Survival to hospital admission	7975 (28.5%)	13 783 (27.0%)	1.03 (0.99, 1.07)	0.17	24 793 (27.4%)	0.94 (0.91, 0.97)	<0.001
Favorable neurological discharge	2684 (9.6%)	3136 (6.2%)	0.80 (0.75, 0.85)	<0.001	7632 (8.4%)	0.87 (0.82, 0.92)	<0.001
Adjusted for bystander CPR			0.82 (0.77, 0.88)	<0.001		0.88 (0.83, 0.93)	<0.001

All models adjusted for fixed effects of patient age, sex, and race, whether the arrest was witnessed, location of cardiac arrest, and initial cardiac arrest rhythm as well as neighborhood race and neighborhood income. Census tract neighborhood was modeled as random effect in the hierarchical models. CPR indicates cardiopulmonary resuscitation; OR, odds ratio.
*Reference groups for the neighborhood race and income analyses are predominantly (>80%) white and high-income (median household income >$80 000) neighborhoods.

differences. This suggests that other aspects of resuscitation care may differ by neighborhood, including paramedic training, number of EMS responders, CPR quality, and delivery of other aspects of acute cardiac life support. These resuscitation care factors were not collected within CARES and are difficult to quantify but certainly deserve closer scrutiny, as it is unclear from our findings if a sole focus of merely increasing CPR training and bystander CPR delivery in majority black and low- and middle-income neighborhoods is sufficient to eliminate the differences in survival outcomes by neighborhood race and income.

On the other hand, our findings that rates of survival to hospital admission did not differ by neighborhood race and yielded only small differences by neighborhood income may also suggest that overall survival differences may be due to neighborhood differences in postresuscitation hospital care.[17] Indeed, prior studies have reported that racial differences in in-hospital cardiac arrest survival are, in part, attributable to the racial composition of the hospital at which one receives care,[18] although the reasons for this (eg, differences in resources or expertise in intensive care) are unclear. Therefore, efforts to reduce neighborhood disparities in survival for out-of-hospital cardiac arrest may also need to address differences in hospital care. Of course, some of the difference in rates of overall survival and favorable neurological survival may still be due to prehospital care, especially if the clinical impact of neighborhood differences in EMS treatment times, bystander CPR, CPR quality, and other aspects of resuscitation care are not fully appreciated until after hospital arrival.

Finally, it is notable that lower rates of survival to discharge for black patients with out-of-hospital cardiac arrest were largely attenuated after controlling for the racial and income composition of the neighborhood in which the individual had the event (OR for black versus white patients went from 0.86 to 0.95). This indicates that a substantial proportion of the existing racial disparities in survival for out-of-hospital cardiac arrest may be modifiable if effective interventions are designed and implemented in the most vulnerable communities. To date, however, most efforts, such as CPR training, have been performed more often in white and wealthier communities.[16] This suggests a critical need to develop systems of care to deliver training and interventions to those communities with the lowest cardiac arrest survival rates, many of which are predominantly black and non–high income.

Table 3. Likelihood of Survival to Discharge by Different Combinations of Neighborhood Race and Income Strata

Neighborhood Race and Income Stratum	Adjusted OR (95% CI)	*P* Value
>80% White and >$80 000	Reference	Reference
Low income (<$40 000)		
>50% Black	0.81 (0.74, 0.89)	<0.001
Integrated	0.84 (0.78, 0.91)	<0.001
>80% White	0.89 (0.80, 0.99)	0.03
Middle income ($40 000 to $80 000)		
>50% Black	0.73 (0.65, 0.83)	<0.001
Integrated	0.90 (0.84, 0.96)	0.002
>80% White	0.84 (0.79, 0.90)	<0.001
High income (>$80 000)		
>50% black	NA*	NA*
Integrated	0.92 (0.84, 1.00)	0.058

OR indicates odds ratio.
*No estimate provided as there were only 533 patients (0.3% of entire cohort) in this stratum, making model estimates for this group unreliable.

Our study should be interpreted in the context of the following limitations. First, our study was an observational study that evaluated associations between neighborhood race and income and survival outcomes. These associations may be due to neighborhood differences in resources such as EMS funding and basic life support training for bystander CPR, which may be the focus of future public health policy initiatives to address neighborhood disparities in survival outcomes for out-of-hospital cardiac arrest. However, they may also be due, in part, to neighborhood-level differences in comorbidities. These are not collected within CARES to minimize the burden of data submission given the large volume of out-of-hospital cardiac arrest cases collected annually and may represent unmeasured confounding. Second, although we were able to define survival differences by neighborhood race and income and assess the impact of neighborhood differences in bystander CPR rates, we were unable to fully account for the differences in survival because information on many aspects of acute resuscitation care before hospital arrival was not available. Moreover, data on EMS arrival and treatment times were incomplete. Although we conducted sensitivity analyses to examine their impact, these sensitivity analyses should be interpreted with some caution. Third, CARES does not systematically collect data on postresuscitation intensive care as it is primarily an out-of-hospital cardiac arrest registry. Although our findings suggest that some of the survival differences by neighborhood race and income were likely due to postresuscitation care in hospitals, we were not able to identify which aspects of postresuscitation care contributed to such survival differences. Finally, although this study encompassed communities representing nearly one third of the US population, our findings may not apply to communities that do not participate in CARES.

In conclusion, we found that a neighborhood's racial and income composition influences the likelihood that an individual survives an out-of-hospital cardiac arrest. Bystander CPR accounted for some but not all of these differences, and unmeasured patient illness severity by race and income could partially explain our findings. Nonetheless, our findings suggest that differences in other aspects of EMS response that differ by neighborhood race and income may be important to address. Moreover, the lack of neighborhood differences in rates of survival to hospital admission implies that overall survival differences may also be due to differences in postresuscitation care at hospitals. Our findings suggest the need to improve not only bystander CPR rates but also other aspects of EMS treatment and postresuscitation care in communities that are majority black and non–high income.

Acknowledgments

Dr Chan had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Sources of Funding

Dr Chan is supported by an R01 grant (1R01HL123980) from the National Heart, Lung, and Blood Institute.

Disclosures

Dr Chan has received funding support from the American Heart Association, which currently helps to fund the CARES registry. CARES was funded by the Centers for Disease Control and Prevention from 2004 to 2012. The program is now supported through private funding from the American Red Cross, the American Heart Association, and in-kind support from Stryker Physio-Control and Emory University. Dr McNally is supported by grant funding from CARES and serves as Executive Director of the program. None of these funding partners had a role in the study design, data analysis, or manuscript preparation and revision. The remaining authors have no disclosures to report.

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SUPPLEMENTAL MATERIAL

Table S1. Detailed Model with Patient Factors and Neighborhood Race and Income.

	Adjusted OR (95% CI)	*P* value
PATIENT LEVEL VARIABLES		
Age, per year	0.98 (0.98, 0.98)	<0.001
Female sex	1.18 (1.14, 1.23)	<0.001
Patient race		
White	Reference	Reference
Black	0.95 (0.89, 1.02)	0.19
Other	0.91 (0.85, 0.97)	0.005
Unknown	1.03 (0.99, 1.08)	0.17
Location of arrest		
Home		
Public building	2.11 (2.01, 2.22)	<0.001
Public street or highway	1.62 (1.52, 1.72)	<0.001
Recreational facility	2.86 (2.61, 3.13)	<0.001
Other	1.62 (1.34, 1.95)	<0.001
Bystander witnessed	2.48 (2.39, 2.58)	<0.001
Cardiac arrest etology		
Presumed cardiac	Reference	Reference
Respiratory	0.50 (0.47, 0.53)	<0.001
Other	1.09 (0.99, 1.20)	0.09
First cardiac arrest rhythm		
Shockable	Reference	Reference
Non-shockable	0.16 (0.16, 0.17)	<0.001
NEIGHBORHOOD LEVEL VARIABLES		
Race		
Predominantly White (>80%)	Reference	Reference
Majority Black (>50%)	0.88 (0.82, 0.95)	<0.001
Integrated	1.00 (0.96, 1.04)	0.93
Annual median household income		
>$80,000	Reference	Reference
$40,000 to $80,000	0.89 (0.85, 0.94)	<0.001
<$40,000	0.88 (0.83, 0.94)	<0.001

Table S2. EMS Arrival and Treatment Times by Neighborhood Race and Median Household Income.

	NEIGHBORHOOD RACE				
	>80% White*	**>50% Black**		**Integrated**	
	n = 63,501	**n = 28,144**	***P***	**n = 77,857**	***P***
Time to EMS Arrival					
Median (IQR), minutes	9.0 (6.8, 12.1)	9.0 (7.0, 12.0)	0.008	8.2 (6.3, 11.0)	<0.001
Missing	12,565	13,059		25,165	
EMS Treatment Time					
Median (IQR), minutes	23.4 (16.7, 33.2)	19.7 (13.0, 29.0)	<0.001	21.0 (14.7, 30.0)	<0.001
Missing	24,463	12,634		37,432	

	NEIGHBORHOOD INCOME				
	> $80,000*	**< $40,000**		**$40,000 to $80,000**	
	n = 27,935	**n = 51,087**	***P***	**n = 90,480**	***P***
Time to EMS Arrival					
Median (IQR), minutes	9.0 (7.0, 12.0)	8.0 (6.0, 11.0)	<0.001	8.9 (6.6, 12.0)	<0.001
Missing	9380	17,821		23,588	
EMS Treatment Time					
Median (IQR), minutes	22.8 (16.0, 31.4)	21.0 (14.0, 30.2)	<0.001	22.0 (15.2, 31.5)	<0.001
Missing	14,329	21,361		38,839	

* Reference groups for the neighborhood race and income analyses are predominantly (>80%) white and high-income (median household income >$80,000) neighborhoods.

EMS, emergency medical services; IQR, interquartile range

Table S3. Sequential Models for the Association Between Neighborhood Race and Income and Survival to Discharge.* Among patients with complete times for EMS arrival and EMS treatment, the impact of sequential adjustment for bystander CPR and then EMS arrival and treatment times for the outcome of survival to discharge is shown.

	Adjusted OR (95% CI)	***P***
Neighborhood Race		
> 80% White	Reference	Reference
Integrated		
Initial Model	0.99 (0.94, 1.04)	0.73
+ Adjustment for Bystander CPR	1.00 (0.95, 1.05)	0.97
+ Adjustment for EMS Arrival and Treatment Times	1.00 (0.95, 1.05)	0.95
> 50% Black		
Initial Model	0.80 (0.72, 0.88)	<0.001
+ Adjustment for Bystander CPR	0.82 (0.74, 0.90)	<0.001
+ Adjustment for EMS Arrival and Treatment Times	0.82 (0.74, 0.90)	<0.001
Neighborhood Median Income		
> $80,000	Reference	Reference
$40,000 to $80,000		
Initial Model	0.88 (0.82, 0.94)	<0.001
+ Adjustment for Bystander CPR	0.89 (0.83, 0.95)	<0.001
+ Adjustment for EMS Arrival and Treatment Times	0.89 (0.84, 0.95)	<0.001
< $80,000		
Initial Model	0.81 (0.78, 0.91)	<0.001
+ Adjustment for Bystander CPR	0.84 (0.78, 0.91)	<0.001
+ Adjustment for EMS Arrival and Treatment Times	0.84 (0.78, 0.91)	<0.001

* Initial model estimates by neighborhood race and income in this table differ from the main study cohort (Table 2) as these results are based on only those patients with complete data on EMS arrival and treatment times.

Table S4. Survival Outcomes by Neighborhood Race and Income for Witnessed Out-of-Hospital Cardiac Arrests.

NEIGHBORHOOD RACE

Outcome	>80% White* n = 30,241	>50% Black n = 10,569	Adjusted OR (95% CI)	*P*	Integrated n = 34,061	Adjusted OR (95% CI)	*P*
Primary Outcome							
Survival to Hospital Discharge	5092 (16.8%)	1273 (12.0%)	0.89 (0.82, 0.98)	0.02	5793 (17.0%)	0.99 (0.95, 1.04)	0.83
Secondary Outcomes							
Bystander CPR	15,511 (51.3%)	3532 (33.4%)	0.67 (0.63, 0.72)	<0.001	16,204 (47.6%)	0.91 (0.87, 0.94)	<0.001
Survival to Hospital Admission	11,301 (37.4%)	3549 (33.6%)	0.98 (0.92, 1.04)	0.51	13,729 (40.3%)	1.11 (1.07, 1.15)	<0.001
Favorable Neurological Discharge	4457 (14.8%)	820 (7.8%)	0.75 (0.67, 0.83)	<0.001	4816 (14.2%)	0.96 (0.91, 1.01)	0.12

NEIGHBORHOOD INCOME

	> $80,000* n = 12,905	< $40,000 n = 20,694	Adjusted OR (95% CI)	*P*	$40,000 to $80,000 n = 41,272	Adjusted OR (95% CI)	*P*
Primary Outcome							
Survival to Hospital Discharge	2370 (18.4%)	2993 (14.5%)	0.83 (0.77, 0.90)	<0.001	6795 (16.5%)	0.88 (0.83, 0.93)	<0.001
Secondary Outcomes							
Bystander CPR	6786 (52.6%)	8154 (39.4%)	0.71 (0.67, 0.75)	<0.001	20,307 (49.2%)	0.89 (0.85, 0.93)	<0.001
Survival to Hospital Admission	5119 (39.7%)	7826 (37.8%)	0.98 (0.92, 1.03)	0.40	15,634 (37.9%)	0.92 (0.88, 0.97)	<0.001
Favorable Neurological Discharge	2059 (16.0%)	2234 (10.9%)	0.76 (0.70, 0.83)	<0.001	5800 (14.1%)	0.87 (0.81, 0.92)	<0.001

* Reference groups for the neighborhood race and income analyses are predominantly (>80%) white and high-income (median household income >$80,000) neighborhoods.

Table S5. Survival Outcomes by Neighborhood Race and Income for Shockable Out-of-Hospital Cardiac Arrests.

NEIGHBORHOOD RACE

Outcome	>80% White* n = 15,581	>50% Black n = 4351	Adjusted OR (95% CI)	*P*	Integrated n = 17,228	Adjusted OR (95% CI)	*P*
Primary Outcome							
Survival to Hospital Discharge	4436 (28.5%)	960 (22.1%)	0.79 (0.69, 0.90)	<0.001	5000 (29.0%)	0.97 (0.91, 1.04)	0.38
Secondary Outcomes							
Bystander CPR	8523 (54.7%)	1395 (32.1%)	0.65 (0.57, 0.74)	<0.001	8681 (50.4%)	0.91 (0.85, 0.97)	0.003
Survival to Hospital Admission	7460 (47.9%)	1814 (41.7%)	0.81 (0.72, 0.92)	0.001	8601 (49.9%)	1.04 (0.97, 1.11)	0.25
Favorable Neurological Discharge	4032 (25.9%)	747 (17.2%)	0.72 (0.62, 0.83)	<0.001	4461 (25.9%)	0.96 (0.90, 1.03)	0.27

NEIGHBORHOOD INCOME

	> $80,000* n = 6897	< $40,000 n = 9393	Adjusted OR (95% CI)	*P*	$40,000 to $80,000 n = 20,870	Adjusted OR (95% CI)	*P*
Primary Outcome							
Survival to Hospital Discharge	2123 (30.8%)	2417 (25.7%)	0.77 (0.69, 0.85)	<0.001	5856 (28.0%)	0.87 (0.80, 0.95)	0.001
Secondary Outcomes							
Bystander CPR	3874 (56.2%)	3829 (40.8%)	0.64 (0.58, 0.70)	<0.001	10,896 (52.2%)	0.86 (0.79, 0.93)	<0.001
Survival to Hospital Admission	3479 (50.4%)	4356 (46.4%)	0.86 (0.78, 0.94)	0.002	10,040 (48.1%)	0.91 (0.84, 0.99)	0.02
Favorable Neurological Discharge	1945 (28.2%)	2042 (21.7%)	0.73 (0.66, 0.81)	<0.001	5253 (25.2%)	0.86 (0.79, 0.94)	<0.001

* Reference groups for the neighborhood race and income analyses are predominantly (>80%) white and high-income (median household income >$80,000) neighborhoods.