Journal of the American Heart Association

ORIGINAL RESEARCH

Association of Racial Residential Segregation With Long-Term Outcomes and Readmissions After Out-of-Hospital Cardiac Arrest Among Medicare Beneficiaries

Ethan E. Abbott, DO, MSCR; David G. Buckler, MUSA; Jesse Y. Hsu, PhD; Benjamin S. Abella, MD, MPhil; Lynne D. Richardson, MD; Brendan G. Carr, MD, MS; Alexis M. Zebrowski, PhD, MPH

BACKGROUND: The national impact of racial residential segregation on out-of-hospital cardiac arrest outcomes after initial resuscitation remains poorly understood. We sought to characterize the association between measures of racial and economic residential segregation at the ZIP code level and long-term survival and readmissions after out-of-hospital cardiac arrest among Medicare beneficiaries.

METHODS AND RESULTS: In this retrospective cohort study, using Medicare claims data, our primary predictor was the index of concentration at the extremes, a measure of racial and economic segregation. The primary outcomes were death up to 3 years and readmissions. We estimated hazard ratios (HRs) across all 3 types of index of concentration at the extremes measures for each outcome while adjusting for beneficiary demographics, treating hospital characteristics, and index hospital procedures. In fully adjusted models for long-term survival, we found a decreased hazard of death and risk of readmission for beneficiaries residing in the more segregated White communities and higher-income ZIP codes compared with the more segregated Black communities and lower-income ZIP codes across all 3 indices of concentration at the extremes measures (race: HR, 0.87 [95% CI, 0.81–0.93]; income: HR, 0.75 [95% CI, 0.69–0.78]; and race+income: HR, 0.77 [95% CI, 0.72–0.82]).

CONCLUSIONS: We found a decreased hazard of death and risk for readmission for those residing in the more segregated White communities and higher-income ZIP codes compared with the more segregated Black communities and lower-income ZIP codes when using validated measures of racial and economic segregation. Although causal pathways and mechanisms remain unclear, disparities in outcomes after out-of-hospital cardiac arrest are associated with the structural components of race and wealth and persist up to 3 years after discharge.

Key Words: health disparities ■ long-term outcomes ■ out-of-hospital cardiac arrest ■ racial residential segregation

Over 400 000 cases of out-of-hospital cardiac arrest (OHCA) occur each year in the United States, with overall low rates of survival to discharge and often with poor functional neurologic status.[1–4] Known racial and ethnic disparities in the incidence and short-term survival following OHCA have been

Correspondence to: Ethan E. Abbott, DO, MSCR, Department of Emergency Medicine, Icahn School of Medicine at Mount Sinai, 1 Gustave L. Levy Place, Box 1620, New York, NY 10029. Email: ethan.abbott@mountsinai.org

Supplemental Material is available at https://www.ahajournals.org/doi/suppl/10.1161/JAHA.123.030138

Preprint posted on MedRxiv, October 7, 2022. doi: https://doi.org/10.1101/2022.10.05.22280740.

This article was sent to Sula Mazimba, MD, MPH, Associate Editor, for review by expert referees, editorial decision, and final disposition.

For Sources of Funding and Disclosures, see page 10.

JAHA is available at: www.ahajournals.org/journal/jaha

CLINICAL PERSPECTIVE

What Is New?

- Racial and ethnic disparities in incidence and short-term survival following out-of-hospital cardiac arrest (OHCA) have been identified, but the association of racial residential segregation and long-term outcomes and readmissions is not known.
- Using a retrospective Medicare OHCA cohort, an examination of the association of the index of concentration at the extremes, a validated measure of racial and economic segregation, and survival up to 3 years and readmissions was undertaken.
- It was determined that index of concentration at the extremes measures of racial and economic segregation was associated with a decreased hazard of death for those residing in the more highly segregated White communities and predominately higher-income ZIP codes relative to those in the more highly segregated Black communities and lower-income ZIP codes; the income measure was the strongest predictor, with a 27% decrease in the hazard of death for those beneficiaries residing in higher-income ZIP codes, with similar trends seen for readmissions.

What Are the Clinical Implications?

- The association of measures of racial and economic segregation with disparities in long-term OHCA outcomes and readmission risk suggests that spatial and living environments, and key social determinants of health, should be considered before OHCA survivors are discharged back to their communities.
- Policy makers, health system leaders, and community stakeholders should focus efforts on communities impacted by the deleterious effects of racial and economic segregation to better address the needs of Medicare beneficiaries after OHCA to improve long-term survival and risk of hospital readmission.

Nonstandard Abbreviations and Acronyms

ICE	index of concentration at the extremes
OHCA	out-of-hospital cardiac arrest

identified across multiple studies.[2,3,5–10] Prior work has established that overall, OHCA survivors are a vulnerable patient population. High mortality and frequent readmissions are noted among those who survive to discharge from their index hospitalization.[11,12] However, longitudinal outcome data among OHCA survivors are difficult to ascertain, resulting in an important knowledge gap. As a result, questions remain about the magnitude of disparities following initial resuscitation.

Racial residential segregation is the extent of geographic or spatial separation of racial and ethnic groups.[13] In the United States, this is the result of long-standing structural and institutional discrimination, which has led to demonstrated disparities in outcomes across multiple health conditions.[14–18] Race and ethnicity are social constructs with no biological basis, and racial residential segregation exemplifies one potential factor that perpetuates disparities in health outcomes. Our prior work examining the association between measures of racial and economic residential segregation and survival to discharge after OHCA demonstrated a lower likelihood of survival to discharge among Medicare beneficiaries residing in predominately Black communities and lower-income ZIP codes compared with White communities and higher-income ZIP codes.[19] The mechanisms by which residential segregation influences health outcomes are complex and multifactorial but likely impact quality and access to health care, and they are also spread across other social domains within each specific community. OHCA survivors residing in disadvantaged areas experience amplified disparities attributable to the structural and community effects of segregation that affect health and social resources along their continuum of care and likely impact risk for hospital readmission.

In this study, we sought to characterize the association between measures of racial and economic residential segregation at the ZIP code level and long-term survival up to 3 years, as well as the risk of hospital readmission after OHCA. This was specifically examined among Medicare beneficiaries while accounting for beneficiary demographics, treating hospital characteristics, and procedures performed during index hospitalization.

METHODS

Study Population

We performed a retrospective observational cohort study, using age-eligible (≥65 years old) Medicare fee-for-service claims data from the Medicare Provider Analysis and Review and Outpatient Research Identifiable Files for January 2013 to December 2015. We abstracted individual patient demographics, including race and ethnicity, sex, and age, from the Medicare Beneficiary Summary file. Beneficiary date of death was determined from the Vital Status File, containing validated dates of death up to June 2019. Claims were excluded if the patient age was <65 years at the start of the study period. Beneficiary-level race was characterized as Black, White, or other (other included the following Medicare-designated racial and ethnic groups: Hispanic, Asian/Native Hawaiian, or Pacific Islander, and Alaska Native or American Indian). Because of the small distribution of beneficiaries with race or ethnicity categorized as other, the final analysis focused specifically on outcomes between Black and White beneficiaries.

We identified beneficiaries with emergency department–treated OHCA, using claims with *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*), codes 427.5, 427.4, 427.41, and 427.42 and mapped *International Classification of Diseases, Tenth Revision, Clinical Modification* (*ICD-10-CM*), codes I46, I49.0, I49.01, and I49.02 as the primary or admitting diagnosis, based on prior approaches used for identifying patients with OHCA.[20–22] From this group, we identified beneficiaries who survived to discharge using the discharge destination status variable and date of death from the vital status file. Beneficiaries were included in analyses for long-term survival if their discharge disposition was coded as something other than *dead* or their date of death was after the date of discharge. We excluded beneficiaries who died on the same day as discharge to avoid capturing any misclassified patients (Figure 1). We aggregated discharge destination status into groups: (1) home self-care, (2) home with home health care, (3) hospice, (4) inpatient rehabilitation, (5) other inpatient care, and (6) skilled nursing facility. Beneficiaries with no documented date of death were censored on January 1, 2019. Therefore, beneficiaries had at least 3 years of follow-up data for survival estimates. Interhospital transfers after OHCA were included in models as a separate covariate, and time to death was calculated using the final date of discharge from short-term inpatient hospitalization. For readmission, we identified beneficiaries with inpatient hospital stays following discharge after OHCA from the Medicare Provider Analysis and Review file. To be considered a readmission, we

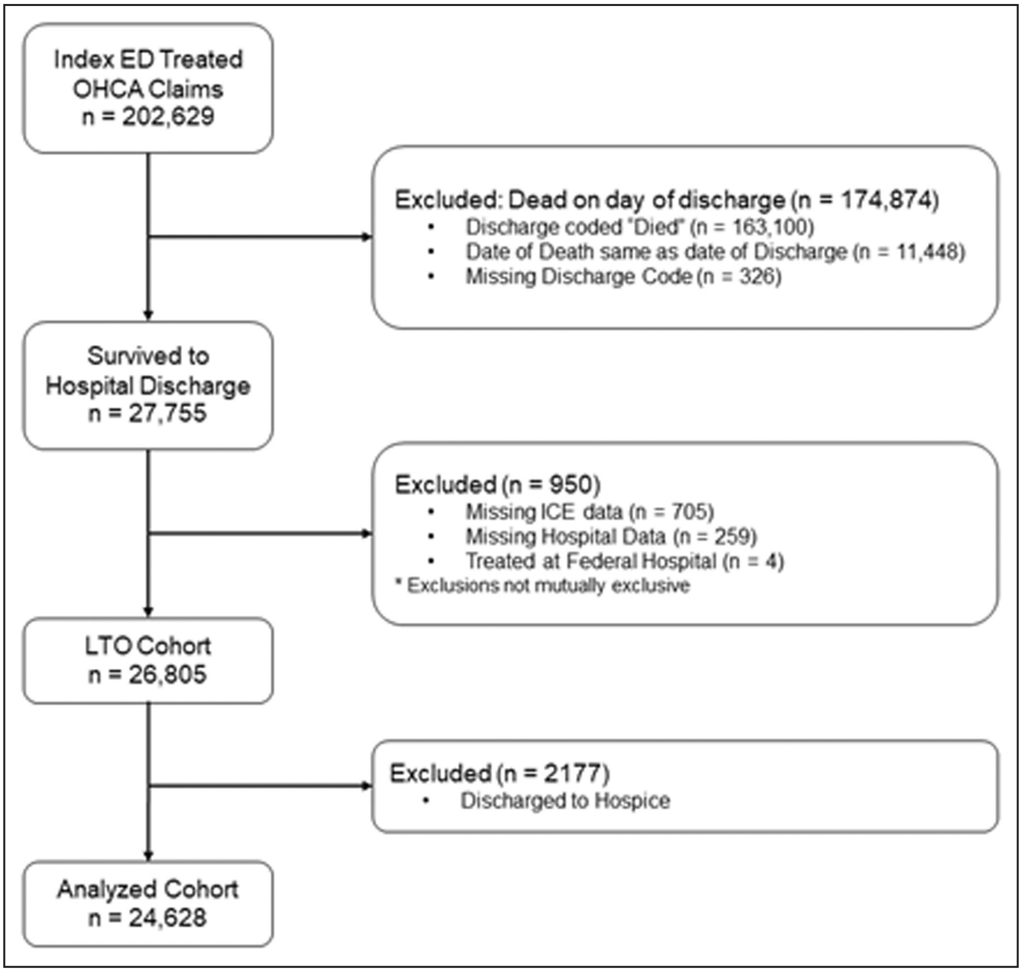

Figure 1. Final Centers for Medicare & Medicaid Services out-of-hospital cardiac arrest (OHCA) cohort.

Long-term outcomes (LTOs) cohort seen in the Table. For the final analytic cohort (survival and Cox proportional hazards models), beneficiaries with discharge destination of hospice were excluded. ED indicates emergency department; and ICE, index of the concentration at the extremes.

included beneficiaries with a new inpatient hospital stay claim starting >1 day after the OHCA discharge. The follow-up period for readmissions was from January 1, 2013, to December 31, 2015, based on currently available data for this study. Treat and release visits to an emergency department were not included in the analyses. Data used in this study are protected under Data Use Agreements between the institutions conducting the research and the Centers for Medicare & Medicaid Services. Data may not be shared by the authors or academic institutions with third parties not covered by the agreements. Requests can be sent to the Research Data Assistance Center.

Index of Concentration at the Extremes

Our primary predictor of interest was the validated index of concentration at the extremes (ICE), which measures racial, income, and a combined racialized income residential segregation. This approach has been refined and adapted by Krieger and colleagues and used in our prior research examining short-term OHCA outcomes.[19,23,24] Krieger and colleagues demonstrated that measures of racialized economic segregation are more robust at identifying associations with poor health outcomes and avoiding potential methodological issues encountered using other approaches.[17,23–25]

The ICE measure is calculated as the difference between the count of a privileged population and a disadvantaged population, divided by the total population. Therefore, the index is the scaled difference between the population counts of the more privileged group and the less privileged group (for operationalized ICE formula, see Figure S1). On the basis of prior work using ICE, we calculated 3 measures: race, income, and race and income combined (racialized income).[24] US Census Bureau American Community Survey 5-year estimates were used to calculate ZIP-code tabulation area racial composition and income ICE measures. These measures were then mapped to the residential ZIP code documented on the first emergency department OHCA claim. All estimates were calculated at the ZIP code level.[26] Population-level Black and White race data were used for racial ICE calculations as these 2 groups represent extreme ends of racial privilege and deprivation for the United States[23] and were also the most represented among the Medicare data sets. For the ICE measures of income, we defined the lowest income group as <$25 000, and ≥$100 000 was used for the highest income group, representative of the 20th and 80th percentiles of income for the United States.[17] Raw values for ICE measures are continuous and range from −1 (most deprived) to 1 (most privileged) (refer to Tables S1 and S2 for raw US ZIP ICE measures by quintile for household income, and percentage below poverty). To better operationalize the measures and improve interpretability, the ZIP code level ICE scores were binned into 5 quintiles, with quintile 5 representing the most economically advantaged ZIP codes and quintile 1 representing the least economically advantaged ZIP codes. For ICE measures of race and income combined, we examined high-income White individuals (income ≥$100 000) and low-income Black individuals (income <$25 000) based on prior work.[17,19,24,25,27] We calculated ZIP code level ICE by subtracting the number of high-income White individuals from the number of low-income Black individuals, divided by the total population for a given ZIP code. These values were binned at the beneficiary level (Figure S1).

Covariates of Interest

Patient Level

Beneficiary comorbidities were identified from secondary diagnoses present on admission in the Medicare Provider Analysis and Review or Outpatient Research Identifiable Files and summarized using the Agency for Healthcare Research and Quality Elixhauser comorbidity index.[28,29] Beneficiary age category (65–74, 75–84, and ≥85 years), sex, and race were pulled from the index hospital claim. OHCA length of stay (LOS) was calculated from the first admission date to the final discharge date (inclusive), including transfers to other short-stay hospital claims. In addition, we identified cardiac catheterization and implantable cardioverter-defibrillator (ICD) placement procedures performed at the first treating hospital using documented procedure codes (Table S3).

Hospital Level

To address confounding from treating hospitals, we selected characteristics from the American Hospital Association Survey data set. Hospital characteristics included number of hospital beds (<100, 100–399, and >400), hospital teaching status (major academic teaching, minor academic teaching, and nonteaching), availability of medical and cardiac intensive care beds (yes/no), and hospital ownership (for profit, nonprofit, and government/nonfederal).

Statistical Analysis

Descriptive statistics were calculated using means with SDs or medians with interquartile ranges, as appropriate for continuous covariates of interest, and frequencies with proportions for nominal variables. To estimate the association of OHCA mortality and ZIP code ICE measures, we constructed 3 models with different primary predictors: (1) ICE race, (2) ICE income, and (3) ICE racialized income (race+income). For our final analytic data set, we excluded all beneficiaries with a discharge destination status of hospice. We first estimated survival using Kaplan-Meier methods (survfit package[30]) for each of the ICE measures independently that included a minimum follow-up period of up to 3 years. For this approach, we used an unweighted estimator. We subsequently fitted a random-effects Cox proportional hazards model. This included a shared frailty term to account for clustering at the hospital level and to estimate hazard ratios (HRs) across all 3 ICE measures. To estimate the association of ICE measures and hazard of readmission, we fitted a competing risk regression model also including the frailty term. We used readmission as the event of interest and mortality as the competing event, while accounting for the above covariates used in the survival models. For the competing risk regression analysis, we used a proportional subdistributional hazard measure to address the competing risks of mortality and readmission. We also performed a sensitivity analysis examining outcomes for a specific combined subgroup that included beneficiaries with a discharge destination status of *home self-care* and *home with home health care*. The purpose of this was to assess if differences in outcomes exist for those discharged to the community who might be differently impacted by racial and economic residential segregation. Because a greater proportion of White beneficiaries with a hospital LOS=1 day compared with Black beneficiaries could impact our findings, we included a sensitivity analysis that captured only beneficiaries with LOS >1 day to assess for potential differences in outcomes. All analyses were conducted using standard statistical software (R, version 4.04; R Core Team, Vienna, Austria). This study was completed in accordance with the strengthening the reporting of observational studies in epidemiology guidelines.[31] The study was reviewed and approved by the Institutional Review Board at the Icahn School of Medicine at Mount Sinai, and informed consent was not required.

RESULTS

We identified 26 805 OHCA claims associated with beneficiaries who survived to discharge following OHCA, with mean beneficiary age of 75 years (SD, 8 years); 39.2% were women, 80.2% were White beneficiaries, 14.1% were Black beneficiaries, and 5.7% were other race beneficiaries (Table). A total of 74.8% (n=20 037) of the overall cohort had a significant comorbidity burden (>5); however, comorbidity burden was similar between Black and White beneficiaries. Median hospital LOS was 5 days (interquartile range, 1–12 days). Overall, 26.3% (n=7063) of beneficiaries underwent cardiac catheterization, and 9.7% (n=2599) received an ICD at the index hospital visit. Survival for the cohort was 56.9% (n=15 264) at 1 year and 42.8% (n=11 461) at 3 years.

After excluding beneficiaries with a discharge destination status of hospice (n=2177), the final analytic data set included 24 628 OHCA claims associated with beneficiaries. Survival rates for each quintile by Kaplan-Meier estimation at 1 year for the ICE race measure ranged from quintile 5 (more segregated White beneficiary ZIP codes) 60.7% (95% CI, 0.60–0.62) to quintile 1 (more segregated Black beneficiary ZIP codes) 58.2% (95% CI, 0.57–0.60) and demonstrated similar rates across the income and racialized income measures. Survival at 3 years for the ICE race measure ranged from 47.2% (95% CI, 0.46–0.49) in quintile 5 (more segregated White individual ZIP codes) to 40.4% (95% CI, 0.39–0.42) in quintile 1 (more segregated Black individual ZIP codes); ICE income measure quintile 5 (high income) 55.8% (95% CI, 0.54–0.57) to quintile 1 (low income) 38.4% (95% CI, 0.37–0.40); and ICE racialized income measure quintile 5 (high income, more segregated White individual ZIP codes) 55.9% (95% CI, 0.55–0.57) to quintile 1 (low income, more segregated Black individual ZIP codes) 39.0% (95% CI, 0.38–0.41) (Figure 2A through 2C and Table S4). Because these Kaplan-Meier estimations are unadjusted for potential confounders, the results should be interpreted carefully given the potential for bias of the estimated effect.

We found a decreased hazard of death in beneficiaries residing in the most racially and economically privileged ZIP codes (quintile 5) compared with the least privileged areas (quintile 1) across all 3 ICE measures (race: HR, 0.87 [95% CI, 0.81–0.93]; income: HR, 0.73 [95% CI, 0.69–0.78]; race+income: HR, 0.77 [95% CI, 0.72–0.82]) (Figure 3A, 3C, and 3E). This result was persistent and statistically significant across all ICE measures and quintiles, except the second quintile in the racialized income (race+income) measure. Among beneficiary-level covariates in all 3 survival models, Black race was associated with an increased hazard of death (race: HR, 1.17 [95% CI, 1.10–1.24]; income: HR, 1.17 [95% CI, 1.11–1.23]; race+income: HR, 1.16 [95% CI, 1.10–1.23]) compared with White race (Figures S2–S4). Beneficiaries who did not undergo cardiac catheterization at the first treating hospital had a 2 times increased hazard of death (HR, 2.01 [95% CI, 1.92–2.11]) compared with those who did. For ICD placement, we also noted 1.6 times increased risk of hazard of death for those who did not undergo placement compared with those who did (HR, 1.60 [95% CI, 1.49–1.72]) (Figures S2–S4).

The most common readmission diagnosis code identified was congestive heart failure (12.7%; n=1402). In models evaluating the association of ICE measures and risk of readmission, we found a decreased risk of readmission for those residing in quintile 5 across all 3 ICE measures (race: HR, 0.87 [95% CI, 0.81–0.93]; income: HR, 0.92 [95% CI, 0.86–0.98]; race+income: HR, 0.87 [95% CI, 0.81–0.93]) compared with quintile 1. We observed an increasing risk of readmission from higher to lower quintiles that persisted and was statistically significant in the race and racialized income model but not observed in the income only model (Figure 3B, 3D, and 3F).

Table. Medicare Beneficiary OHCA Cohort Characteristics 2013 to 2015

Variable	Overall, n (%)	White beneficiaries, n (%)	Black beneficiaries, n (%)	Other beneficiaries, n (%)*
OHCA cohort characteristics (beneficiary level)	26 805	21 499 (80.2)	3783 (14.1)	1523 (5.7)
Sex				
Women	10 500 (39.2)	7898 (36.7)	2036 (53.8)	566 (37.2)
Men	16 305 (60.8)	13 601 (63.3)	1747 (46.2)	957 (62.8)
Age group category				
65–74 y	13 865 (51.7)	10 814 (50.3)	2169 (57.3)	882 (57.9)
75–84 y	9091 (33.9)	7543 (35.1)	1133 (29.9)	415 (27.2)
≥85 y	3849 (14.4)	3142 (14.6)	481 (12.7)	226 (14.8)
AHRQ comorbidity index				
<0	2560 (9.6)	2202 (10.2)	239 (6.3)	119 (7.8)
0	2035 (7.6)	1832 (8.5)	116 (3.1)	87 (5.7)
1–4	1595 (6.0)	1390 (6.5)	122 (3.2)	83 (5.4)
≥5	20 037 (74.8)	15 588 (72.5)	3236 (85.5)	1213 (79.6)
NA	578 (2.2)	487 (2.3)	70 (1.9)	21 (1.4)
Hospital length of stay, median (IQR), d	5.00 (1.00–12.00)	5.00 (1.00–11.00)	8.00 (3.00–16.00)	7.00 (3.00–16.00)
Cardiac catheterization at index hospitalization	7063 (26.3)	5929 (27.6)	720 (19.0)	414 (27.2)
ICD at index hospitalization	2599 (9.7)	2170 (10.1)	288 (7.6)	141 (9.3)
Index treating hospital characteristics (beneficiary level)				
No. of hospital beds				
<100	4004 (14.9)	3556 (16.5)	309 (8.2)	139 (9.1)
100–399	14 334 (53.5)	11 627 (54.1)	1799 (47.6)	908 (59.6)
>400	8467 (31.6)	6316 (29.4)	1675 (44.3)	476 (31.3)
Hospital teaching status†				
Major teaching	3668 (13.7)	2517 (11.7)	924 (24.4)	227 (14.9)
Minor teaching	9504 (35.5)	7549 (35.1)	1355 (35.8)	600 (39.4)
Nonteaching	13 633 (50.9)	11 433 (53.2)	1504 (39.8)	696 (45.7)
Hospital ownership status				
For profit	4172 (15.6)	3282 (15.3)	625 (16.5)	265 (17.4)
Government (nonfederal)	3411 (12.7)	2625 (12.2)	574 (15.2)	212 (13.9)
Nonprofit	19 222 (71.7)	15 592 (72.5)	2584 (68.3)	1046 (68.7)
Hospital critical care bed availability				
MICU and CICU beds	16 120 (60.1)	12 605 (58.6)	2559 (67.6)	956 (62.8)
CICU beds only (no MICU beds)	259 (1.0)	207 (1.0)	27 (0.7)	25 (1.6)
MICU beds only (no CICU beds)	8936 (33.3)	7380 (34.3)	1067 (28.2)	489 (32.1)
No MICU or CICU beds	1490 (5.6)	1307 (6.1)	130 (3.4)	53 (3.5)
Cardiac catheterization capability by hospital				
Cardiac catheterization yes	18 340 (68.4)	14 586 (67.8)	2693 (71.2)	1061 (69.7)
Cardiac catheterization no	8465 (31.6)	6913 (32.2)	1090 (28.8)	462 (30.3)

Outcome	Overall beneficiaries, n (%)	Black beneficiaries, n (%)	White beneficiaries, n (%)	Other beneficiaries, n (%)*
Discharge destination status				
Home self-care	9142 (34.1)	7614 (35.4)	1025 (27.1)	503 (33.0)
Home with home health care	3560 (13.3)	2850 (13.3)	506 (13.4)	204 (13.4)
Hospice‡	2803 (10.5)	2068 (9.6)	573 (15.1)	162 (10.6)

(*Continued*)

Table. Continued

Outcome	Overall beneficiaries, n (%)	Black beneficiaries, n (%)	White beneficiaries, n (%)	Other beneficiaries, n (%)*
Inpatient rehabilitation	397 (1.5)	313 (1.5)	52 (1.4)	32 (2.1)
Other inpatient care	5219 (19.5)	4384 (20.4)	580 (15.3)	255 (16.7)
Skilled nursing facility	5684 (21.2)	4270 (19.9)	1047 (27.7)	367 (24.1)
Overall survival				
Alive at 1 y	15 264 (56.9)	12 598 (58.6)	1780 (47.1)	886 (58.2)
Alive at 3 y	11 461 (42.8)	9554 (44.4)	1226 (32.4)	681 (44.7)

AHRQ indicates Agency for Healthcare Research and Quality; CICU, oronary intensive care unit; ICD, implantable cardioverter-defibrillator; IQR, interquartile range; MICU, medical intensive care unit; NA, not available; and OHCA, out-of-hospital cardiac arrest.

*Other (Centers for Medicare & Medicaid Services defined racial and ethnic categories): Hispanic; Asian/Native Hawaiian or Pacific Islander; American Indian or Alaska Native.

†Hospital teaching status categories from American Hospital Association data set: major teaching=member of Council of Teaching Hospital of the Association of American Medical Colleges, minor teaching=medical school affiliation reported to American Medical Association, and nonteaching=all other hospitals.

‡Hospice beneficiaries excluded from the final analytic data set.

In the sensitivity analysis examining the association of ICE measures with survival and risk of readmission among a subgroup of beneficiaries with discharge destination status of home self-care and home with home health care (n=12 702), we found a decreased hazard of death for quintile 5 (race: HR, 0.87 [95% CI, 0.79–0.95]; income: HR, 0.67 [95% CI, 0.62–0.73]; race+income: HR, 0.69 [95% CI, 0.63–0.76]) compared with quintile 1 (Figure 3). There were several notable differences compared with the primary analysis that included all discharge groups. In the ICE race model examining this subset of beneficiaries who were discharged home, we did not observe the same trend; there was a decreased hazard of death and increased readmission risk in quintile 4 compared with quintile 5. We also found that ICE measures of income and racialized income in quintile 5 were most strongly associated with a decreased risk of readmission compared with the other quintiles. In the sensitivity analysis that included only beneficiaries with LOS >1 day, we found similar trends in outcomes across all 3 measures and both outcomes.

DISCUSSION

In this study of Medicare beneficiaries who survived to discharge after an OHCA, we demonstrated that ICE measures of racial and economic segregation were associated with a decreased hazard of death for those residing in more highly segregated White communities and predominately higher-income ZIP codes relative to those residing in more highly segregated Black communities and lower-income ZIP codes. Of the 3 ICE measures, the income measure was the strongest predictor, with a 27% decrease in the hazard of death for those beneficiaries residing in quintile 5 compared with quintile 1. This reduction in hazard of death was present and persistent across all 3 ICE measures and quintiles, except for racialized income measure quintile 2. We also found similar disparities in outcomes for models examining the association of ICE measures and risk of readmission; beneficiaries residing in higher-income more segregated White community ZIP codes demonstrated a 13% decreased risk of readmission after OHCA compared with those residing in lower-income more segregated Black community ZIP codes.

Several studies have yielded contrasting results about racial and ethnic disparities in long-term survival. Among a cohort of elderly patients with OHCA, Chan and colleagues found overall 1-year mortality rates of 31.8% and 3-year rates of 47.2%, but found no long-term survival differences by individual race when examined in a subgroup analysis using registry data linked to Medicare claims.[32] Coppler et al also noted no long-term differences in survival based on race, but found disparities based on sex, socioeconomic status, and geographic posthospital access to care. This contrasts to a more recent in-hospital cardiac arrest study that found lower survival among Black patients at 1, 3, and 5 years after adjustment for hospital site.[33] Another recent study using updated registry data linked to Medicare data, also by Chan and colleagues, evaluating long-term survival and readmission risk for OHCA survivors, found high mortality at 3 months after discharge (27%), with 40.1% of the cohort readmitted at 1 year and 52.4% readmitted at 3 years.[34] Our results suggest that there exists a strong association between racial and economic segregation and long-term survival and risk of readmission after OHCA, which may be related to important factors related to residential communities and social context after discharge. Key social determinants, such as residential segregation, are likely complex and multifactorial, but are important to consider in the context of emergency care conditions, such as OHCA.

We also found ICD placement and cardiac catheterization were strong predictors for survival across all 3 ICE measures; beneficiaries who did not undergo

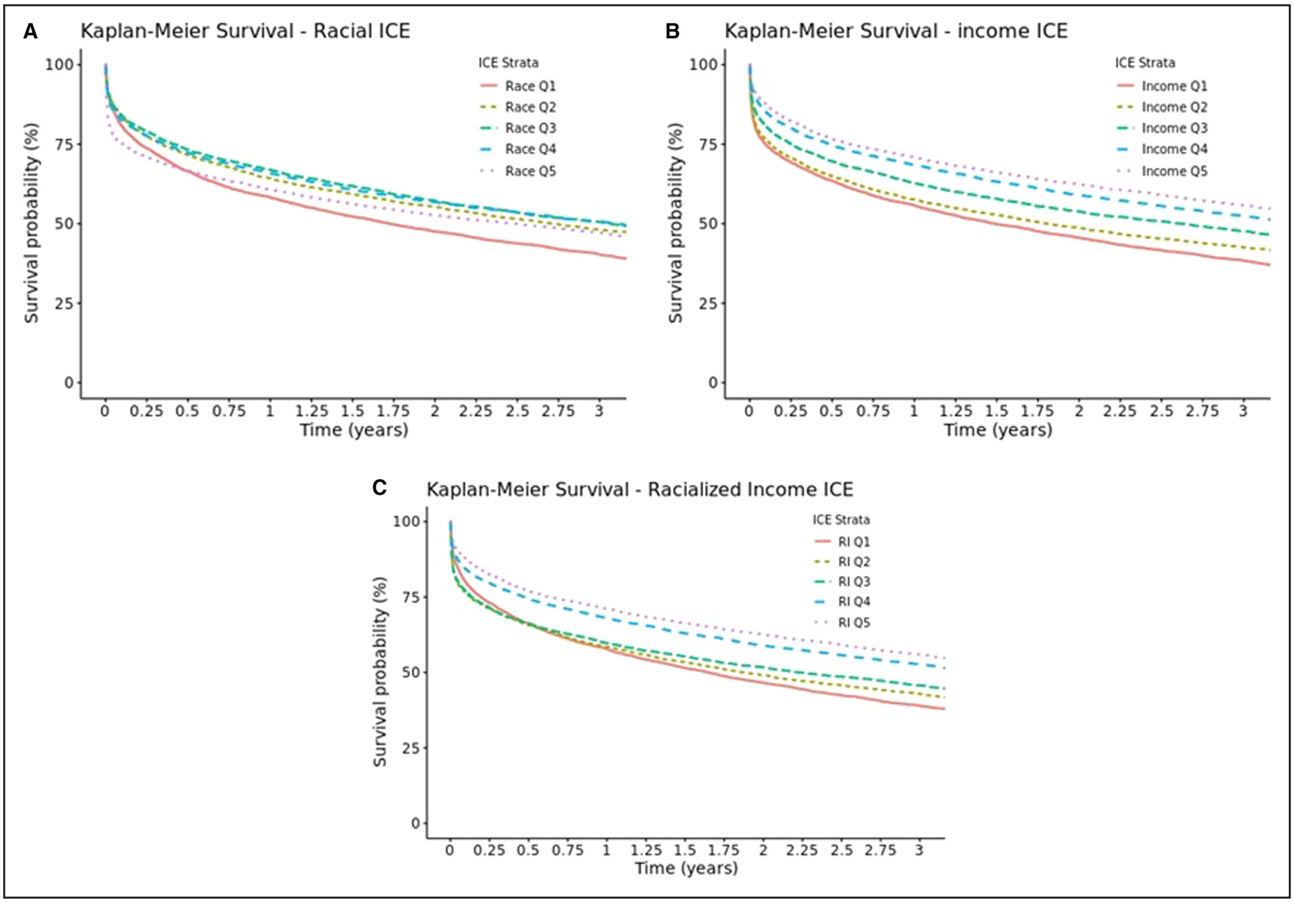

Figure 2. Kaplan-Meier survival curves by index of the concentration at the extremes (ICE) measures.
A, ICE race model quintile 1 (Q1) represents most segregated Black communities, and Q5 represents most segregated White communities. **B**, ICE income model Q1 represents low income (≤$25 000), and Q5 represents high income (≥$100000). **C**, ICE income+race (RI) measure model Q1 represents low-income Black communities, and Q5 represents high-income White communities.

those procedures demonstrated an increased hazard for death. Because claims data do not include granular clinical details, we were unable to determine if specific beneficiaries met precise criteria for these interventions. However, our results are in line with several prior studies. A study of Medicare beneficiaries by Groeneveld et al found a survival benefit for ICD implantation after OHCA for both Black and White beneficiaries. They found that Black beneficiaries had a lower probability of receiving an ICD or coronary revascularization at 90 days among those aged 66 to 74 years even after full adjustment, which included socioeconomic differences.[35] Other studies of ICD placement using Centers for Medicare & Medicaid Services data found lower use of the procedure among Black beneficiaries compared with White beneficiaries, but this was somewhat equalizing by the early 2000s.[36] In a more contemporary study of elderly in-hospital cardiac arrest survivors, Chen and colleagues found Black patients were less likely to undergo coronary revascularization but were as likely to receive an ICD compared with White survivors.[33] Although we found in our cohort a long-term survival benefit among beneficiaries who underwent cardiac catheterization at index hospitalization, there is recent evidence from several randomized controlled trials demonstrating no difference in survival benefit of immediate versus delayed cardiac catheterization after OHCA for both short-term outcomes and survival at 1 year.[37–39] Our findings, in the context of measures of racial residential segregation, may reflect more complex mechanisms occurring along the continuum of care; these results warrant further investigation, where linkage of OHCA data sets with procedural documentation and hospital-level clinical variables can better elucidate pathways leading to disparities.

Although this study was not designed to ascertain causes, racial and economic segregation likely has complex effects on long-term OHCA survival in the context of access to care, quality of care, as well as other important social determinants. Given high rates of readmissions and postdischarge health care use after an OHCA,[11,12] the structural disinvestment that has been noted to occur in the setting of residential segregation could create barriers to fundamental

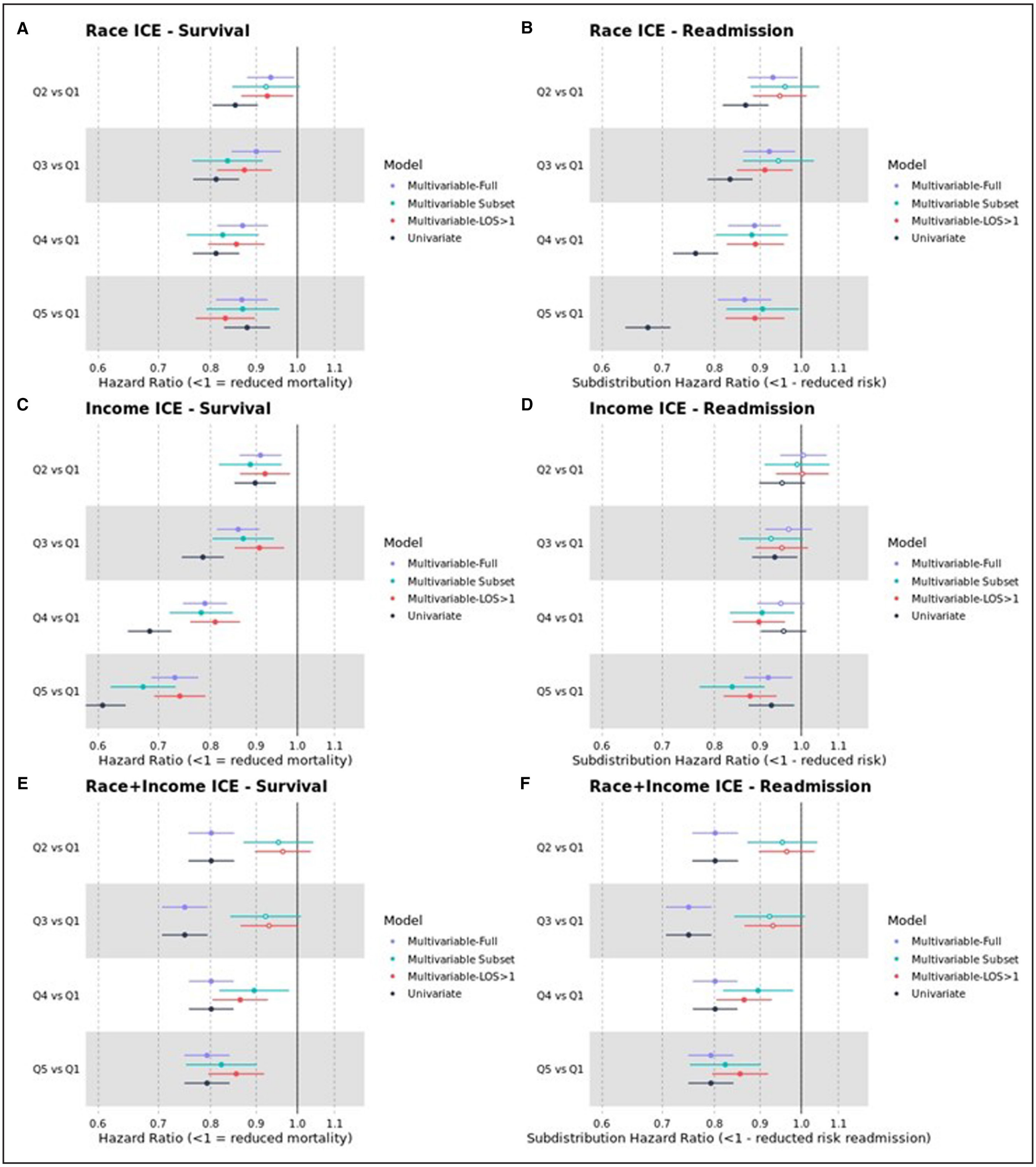

Figure 3. Univariate and multivariable index of concentration at the extremes (CIE) Cox proportional hazards and competing risk regression models forest plots for outcomes of survival and readmission.

Forest plots of Cox proportional hazards ratios for univariate, multivariable, and multivariable subset for all ICE measures for outcomes of survival and readmissions. The multivariable subset models examine the association of outcomes for subgroup of beneficiaries with disposition of *home self-care* and *home with home health care*. For race measure, quintile 1 (Q1)=more segregated Black communities (reference), and Q5=more segregated White communities. For income measure, Q1=low income (reference), and Q5=high income. For race+income (racialized income) ICE measure, Q1=more segregated Black and low-income communities (reference), and Q5=more segregated White and high-income communities. LOS indicates length of stay. Panels A, C, E: Forest plots of ICE models of race, income and race + income for survival outcome. Panels B, D, F: Forest plots for ICE models of race, income, and race + income for readmission outcome.

needs, such as transportation, access to follow-up medical care, medications, and multiple other factors important for elderly OHCA survivors. Although these community factors may play a more important role in longitudinal outcomes, further study is warranted to identify the pathways leading to disparities, and robust data sets are required for this type of study.

Limitations

There are several noted limitations to our study. Claims data lack the granularity of registry data, and thus, we were unable to include important clinical predictors and outcomes seen in other OHCA studies, such as initial arrest rhythm or neurologic status at discharge. ICD diagnosis codes for OHCA have been demonstrated to have lower positive predictive value[40] and may miss or capture patients without OHCA; there is literature validating use of ICD codes for OHCA that supports the current approach.[20] We also found median hospital length of stay to be significantly shorter for White beneficiaries (5 days; interquartile range, 1.00–11.00 days) compared with Black beneficiaries (8 days; interquartile range, 3.00–16.00 days). This could have been the result of misclassification of OHCA cases and potential for impacting our final conclusions. However a sensitivity analysis did not demonstrate major differences in outcomes when including LOS >1 day. Use of beneficiary residence ZIP code may also not capture differences seen at smaller geographic units of analysis, such as neighborhood or census tract, thus impacting our results. We also note that Medicare data include a sample population that is predominately composed of White and elderly beneficiaries, thus limiting our ability to rigorously analyze associations for all racial and ethnic groups in the United States or the impacts of residential segregation on younger survivors. Among our cohort, we estimate beneficiaries who converted to Medicare Advantage plans during the follow-up period was low, but it should be noted as a potential limitation. These beneficiaries may not have been identified as readmissions from our data set, impacting measured differences seen between groups. Despite these limitations, we believe that this study captures important population-level data on OHCA long-term outcomes among an elderly cohort. Furthermore, this work closely examines the complex intersection and deleterious impact of long-standing residential segregation in the United States and its association with health care outcomes using validated measures.

CONCLUSIONS

In this study of Medicare beneficiaries who survived to discharge after OHCA, we found a decreased hazard of death and risk for readmission for those residing in predominately White and higher-income ZIP codes compared with predominately Black and lower-income ZIP codes when using validated measures of racial and economic segregation. Measures of economic segregation based on income were the strongest predictor for long-term survival. Although further study is needed to identify causal factors, develop methods to overcome systemic and institutional racism, and achieve equity in health outcomes for OHCA and other cardiovascular conditions, this study demonstrates that racial and economic segregation variables are associated with disparities in outcomes for OHCA.

ARTICLE INFORMATION

Received March 14, 2023; accepted August 10, 2023.

Affiliations

Department of Emergency Medicine, Icahn School of Medicine at Mount Sinai, New York, NY (E.E.A., D.G.B., L.D.R., B.G.C., A.M.Z.); Department of Biostatistics, Epidemiology, and Informatics, University of Pennsylvania Perelman School of Medicine, Philadelphia, PA (J.Y.H.); Center for Resuscitation Science and Department of Emergency Medicine, University of Pennsylvania, Philadelphia, PA (B.S.A.); Department of Population Health Science and Policy, Icahn School of Medicine at Mount Sinai, New York, NY (E.E.A., L.D.R., B.G.C., A.M.Z.); and (E.E.A., L.D.R.), Institute for Health Equity Research, Icahn School of Medicine at Mount Sinai, New York, NY.

Sources of Funding

This work was supported by a grant from the National Institutes of Health–National Heart, Lung, and Blood Institute (7R01HL141841-03) (principal investigator: Dr Carr). Dr Abbott was supported by the Emergency Medicine Foundation Health Disparities grant 2021 to 2022. This work was supported in part through the computational resources and staff expertise provided by Scientific Computing at the Icahn School of Medicine at Mount Sinai and supported by the Clinical and Translational Science Awards grant UL1TR004419 from the National Center for Advancing Translational Sciences. Research reported in this article was supported by the Office of Research Infrastructure of the National Institutes of Health under award numbers S10OD026880 and S10OD030463. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Disclosures

None.

Supplemental Material

Tables S1–S4
Figures S1–S4

REFERENCES

1. 2020 Annual Report. Cardiac Arrest Registry to Enhance Survival Surveillance. Accessed May 1, 2022. https://mycares.net/sitepages/uploads/2021/2020_flipbook/index.html.
2. Girotra S, van Diepen S, Nallamothu BK, Carrel M, Vellano K, Anderson ML, McNally B, Abella BS, Sasson C, Chan PS, et al. Regional variation in out-of-hospital cardiac arrest survival in the United States. *Circulation*. 2016;133:2159–2168. doi: 10.1161/CIRCULATIONAHA.115.018175
3. Shinozaki K, Nonogi H, Nagao K, Becker LB. Strategies to improve cardiac arrest survival: a time to act. *Acute Med Surg*. 2016;3:61–64. doi: 10.1002/ams2.192
4. Tsao CW, Aday AW, Almarzooq ZI, Alonso A, Beaton AZ, Bittencourt MS, Boehme AK, Buxton AE, Carson AP, Commodore-Mensah Y, et al. Heart disease and stroke statistics-2022 update: a report from the American Heart Association. *Circulation*. 2022;145:e153–e639. doi: 10.1161/CIR.0000000000001052

5. Albaeni A, Beydoun MA, Beydoun HA, Akinyele B, RaghavaKurup L, Chandra-Strobos N, Eid SM. Regional variation in outcomes of hospitalized patients having out-of-hospital cardiac arrest. *Am J Cardiol*. 2017;120:421–427. doi: 10.1016/j.amjcard.2017.04.045
6. Becker LB, Han BH, Meyer PM, Wright FA, Rhodes KV, Smith DW, Barrett J. Racial differences in the incidence of cardiac arrest and subsequent survival. The CPR Chicago Project. *N Engl J Med*. 1993;329:600–606. doi: 10.1056/NEJM199308263290902
7. Reinier K, Nichols GA, Huertas-Vazquez A, Uy-Evanado A, Teodorescu C, Stecker EC, Gunson K, Jui J, Chugh SS. Distinctive clinical profile of blacks versus whites presenting with sudden cardiac arrest. *Circulation*. 2015;132:380–387. doi: 10.1161/CIRCULATIONAHA.115.015673
8. Cowie MR, Fahrenbruch CE, Cobb LA, Hallstrom AP. Out-of-hospital cardiac arrest: racial differences in outcome in Seattle. *Am J Public Health*. 1993;83:955–959. doi: 10.2105/ajph.83.7.955
9. Shah KS, Shah AS, Bhopal R. Systematic review and meta-analysis of out-of-hospital cardiac arrest and race or ethnicity: black US populations fare worse. *Eur J Prev Cardiol*. 2014;21:619–638. doi: 10.1177/2047487312451815
10. Starks MA, Schmicker RH, Peterson ED, May S, Buick JE, Kudenchuk PJ, Drennan IR, Herren H, Jasti J, Sayre M, et al. Association of neighborhood demographics with out-of-hospital cardiac arrest treatment and outcomes: where you live may matter. *JAMA Cardiol*. 2017;2:1110–1118. doi: 10.1001/jamacardio.2017.2671
11. Shuvy M, Morrison LJ, Koh M, Qiu F, Buick JE, Dorian P, Scales DC, Tu JV, Verbeek PR, Wijeysundera HC, et al. Long-term clinical outcomes and predictors for survivors of out-of-hospital cardiac arrest. *Resuscitation*. 2017;112:59–64. doi: 10.1016/j.resuscitation.2016.12.026
12. Yeo I, Cheung JW, Feldman DN, Amin N, Chae J, Wong SC, Kim LK. Assessment of hospital readmission rates, risk factors, and causes after cardiac arrest: analysis of the US nationwide readmissions database. *JAMA Netw Open*. 2019;2:e1912208. doi: 10.1001/jamanetworkopen.2019.12208
13. Massey DS, Denton NA. Hypersegregation in U.S. metropolitan areas: black and Hispanic segregation along five dimensions. *Demography*. 1989;26:373–391. doi: 10.2307/2061599
14. Bailey ZD, Krieger N, Agenor M, Graves J, Linos N, Bassett MT. Structural racism and health inequities in the USA: evidence and interventions. *Lancet*. 2017;389:1453–1463. doi: 10.1016/S0140-6736(17)30569-X
15. Williams DR, Collins C. Racial residential segregation: a fundamental cause of racial disparities in health. *Public Health Rep*. 2001;116:404–416. doi: 10.1093/phr/116.5.404
16. Chambers BD, Baer RJ, McLemore MR, Jelliffe-Pawlowski LL. Using index of concentration at the extremes as indicators of structural racism to evaluate the association with preterm birth and infant mortality-California, 2011-2012. *J Urban Health*. 2019;96:159–170. doi: 10.1007/s11524-018-0272-4
17. Feldman JM, Waterman PD, Coull BA, Krieger N. Spatial social polarisation: using the index of concentration at the extremes jointly for income and race/ethnicity to analyse risk of hypertension. *J Epidemiol Community Health*. 2015;69:1199–1207. doi: 10.1136/jech-2015-205728
18. Kershaw KN, Albrecht SS. Racial/ethnic residential segregation and cardiovascular disease risk. *Curr Cardiovasc Risk Rep*. 2015;9:10. doi: 10.1007/s12170-015-0436-7
19. Abbott EE, Buckler DG, Hsu JY, Jacoby SF, Abella BS, Richardson LD, Carr BG, Zebrowski AM. Survival after out-of-hospital cardiac arrest: the role of racial residential segregation. *J Urban Health*. 2022;99:998–1011. doi: 10.1007/s11524-022-00691-x
20. Shelton SK, Chukwulebe SB, Gaieski DF, Abella BS, Carr BG, Perman SM. Validation of an ICD code for accurately identifying emergency department patients who suffer an out-of-hospital cardiac arrest. *Resuscitation*. 2018;125:8–11. doi: 10.1016/j.resuscitation.2018.01.021
21. Hennessy S, Leonard CE, Freeman CP, Deo R, Newcomb C, Kimmel SE, Strom BL, Bilker WB. Validation of diagnostic codes for outpatient-originating sudden cardiac death and ventricular arrhythmia in Medicaid and Medicare claims data. *Pharmacoepidemiol Drug Saf*. 2010;19:555–562. doi: 10.1002/pds.1869
22. De Bruin ML, van Hemel NM, Leufkens HG, Hoes AW. Hospital discharge diagnoses of ventricular arrhythmias and cardiac arrest were useful for epidemiologic research. *J Clin Epidemiol*. 2005;58:1325–1329. doi: 10.1016/j.jclinepi.2005.04.009
23. Krieger N, Feldman JM, Waterman PD, Chen JT, Coull BA, Hemenway D. Local residential segregation matters: stronger association of census tract compared to conventional city-level measures with fatal and non-fatal assaults (total and firearm related), using the index of concentration at the extremes (ICE) for racial, economic, and racialized economic segregation, Massachusetts (US), 1995-2010. *J Urban Health*. 2017;94:244–258. doi: 10.1007/s11524-016-0116-z
24. Krieger N, Waterman PD, Spasojevic J, Li W, Maduro G, Van Wye G. Public health monitoring of privilege and deprivation with the index of concentration at the extremes. *Am J Public Health*. 2016;106:256–263. doi: 10.2105/AJPH.2015.302955
25. Krieger N, Waterman PD, Gryparis A, Coull BA. Black carbon exposure, socioeconomic and racial/ethnic spatial polarization, and the Index of Concentration at the Extremes (ICE). *Health Place*. 2015;34:215–228. doi: 10.1016/j.healthplace.2015.05.008
26. Abbott EE, Buckler DG, Zebrowski AM, Abella BS, Carr BG. Abstract 134: survival after out-of-hospital cardiac arrest: the role of urban-rural residence and demographic factors. *Circulation*. 2020;142:A134. doi: 10.1161/circ.142.suppl_4.134
27. Westrick AC, Bailey ZD, Schlumbrecht M, Hlaing WM, Kobetz EE, Feaster DJ, Balise RR. Residential segregation and overall survival of women with epithelial ovarian cancer. *Cancer*. 2020;126:3698–3707. doi: 10.1002/cncr.32989
28. Gasparini A. Comorbidity: an R package for computing comorbidity scores. *J Open Source Software*. 2018;3:648. https://doi.org/10.21105/joss.00648
29. Moore BJ, White S, Washington R, Coenen N, Elixhauser A. Identifying increased risk of readmission and In-hospital mortality using hospital administrative data: the AHRQ Elixhauser comorbidity index. *Med Care*. 2017;55:698–705. doi: 10.1097/MLR.0000000000000735
30. Therneau T. Survival Analysis. 3.5-6. Accessed April 5, 2023. https://cran.r-project.org/web/packages/survival/index.html.
31. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP; STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol*. 2008;61:344–349. doi: 10.1016/j.jclinepi.2007.11.008
32. Chan PS, McNally B, Nallamothu BK, Tang F, Hammill BG, Spertus JA, Curtis LH. Long-term outcomes among elderly survivors of out-of-hospital cardiac arrest. *J Am Heart Assoc*. 2016;5:e002924. doi: 10.1161/JAHA.115.002924
33. Coppler PJ, Elmer J, Rittenberger JC, Callaway CW, Wallace DJ. Demographic, social, economic and geographic factors associated with long-term outcomes in a cohort of cardiac arrest survivors. *Resuscitation*. 2018;128:3136. doi: 10.1016/j.resuscitation.2018.04.032
34. Chan PS, McNally B, Chang A, Girotra S, Al-Araji R, Mawani M, Ahn KO, Merritt R. Long-term outcomes for out-of-hospital cardiac arrest in elderly patients: an analysis of cardiac arrest registry to enhance survival data linked to Medicare files. *Circ Cardiovasc Qual Outcomes*. 2022;15:e009042. doi: 10.1161/CIRCOUTCOMES.122.009042
35. Groeneveld PW, Heidenreich PA, Garber AM. Racial disparity in cardiac procedures and mortality among long-term survivors of cardiac arrest. *Circulation*. 2003;108:286–291. doi: 10.1161/01.CIR.0000079164.95019.5A
36. Groeneveld PW, Heidenreich PA, Garber AM. Trends in implantable cardioverter-defibrillator racial disparity: the importance of geography. *J Am Coll Cardiol*. 2005;45:72–78. doi: 10.1016/j.jacc.2004.07.061
37. Lemkes JS, Janssens GN, van der Hoeven NW, Jewbali LSD, Dubois EA, Meuwissen MM, Rijpstra TA, Bosker HA, Blans MJ, Bleeker GB, et al. Coronary angiography after cardiac arrest without ST segment elevation: one-year outcomes of the COACT randomized clinical trial. *JAMA Cardiol*. 2020;5:1358–1365. doi: 10.1001/jamacardio.2020.3670
38. Lemkes JS, Janssens GN, van Royen N. Coronary angiography after cardiac arrest without ST-segment elevation. *N Engl J Med*. 2019;381:189–190. doi: 10.1056/NEJMc1906523
39. Desch S, Freund A, Akin I, Behnes M, Preusch MR, Zelniker TA, Skurk C, Landmesser U, Graf T, Eitel I, et al. Angiography after out-of-hospital cardiac arrest without ST-segment elevation. *N Engl J Med*. 2021;385:2544–2553. doi: 10.1056/NEJMoa2101909
40. DeZorzi C, Boyle B, Qazi A, Luthra K, Khera R, Chan PS, Girotra S. Administrative billing codes for identifying patients with cardiac arrest. *J Am Coll Cardiol*. 2019;73:1598–1600. doi: 10.1016/j.jacc.2019.01.030