Social Determinants of Health and 90-Day Mortality After Hospitalization for Heart Failure in the REGARDS Study

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BACKGROUND: Outcomes following heart failure (HF) hospitalizations are poor, with 90-day mortality rates of 15% to 20%. Although prior studies found associations between individual social determinants of health (SDOH) and post-discharge mortality, less is known about how an individual's total burden of SDOH affects 90-day mortality.

METHODS AND RESULTS: We included participants of the REGARDS (Reasons for Geographic and Racial Differences in Stroke) Study who were Medicare beneficiaries aged ≥65 years discharged alive after an adjudicated HF hospitalization. Guided by the Healthy People 2020 Framework, we examined 9 SDOH. First, we examined age-adjusted associations between each SDOH and 90-day mortality; those associated with 90-day mortality were used to create an SDOH count. Next, we determined the hazard of 90-day mortality by the SDOH count, adjusting for confounders. Over 10 years, 690 participants were hospitalized for HF at 440 unique hospitals in the United States; there were a total of 79 deaths within 90 days. Overall, 28% of participants had 0 SDOH, 39% had 1, and 32% had ≥2. Compared with those with 0, the age-adjusted hazard ratio for 90-day mortality among those with 1 SDOH was 2.89 (95% CI, 1.46–5.72) and was 3.06 (1.51–6.19) among those with ≥2 SDOH. The adjusted hazard ratio was 2.78 (1.37–5.62) and 2.57 (1.19–5.54) for participants with 1 SDOH and ≥2, respectively.

CONCLUSIONS: While having any of the SDOH studied here markedly increased risk of 90-day mortality after an HF hospitalization, a greater burden of SDOH was not associated with significantly greater risk in our population.

Key Words: cohort study • heart failure • mortality • social determinants of health

H eart failure (HF) is the most common cause of hospitalization among Medicare beneficiaries, resulting in 1 million hospitalizations per year.1 While health system-, hospital-, and patient-based interventions have been implemented to improve post-hospitalization outcomes, mortality rates remain high and have worsened in recent years.2,3 This is especially true for Medicare beneficiaries, where 15% to 20% of individuals discharged alive following an HF hospitalization die within 90 days of discharge.4–7 Although severity of HF and comorbidity burden are likely to drive some of this risk of mortality,8,9 an improved understanding of additional factors that contribute to 90-day mortality following an HF hospitalization is necessary to develop interventions to target patients at highest risk.

Studies have sought to understand the effect of social determinants of health (SDOH) on mortality after an HF hospitalization.10,11 SDOH, which are defined as the conditions in which people are born, grow, work, live, age, and the wider set of forces and systems shaping
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the conditions of daily life, may be responsible for a large part of health inequity across various diseases.12 Although not always routinely collected as clinical or physiologic data, SDOH permit a nuanced understanding of the patient, the context in which they live, and their ability to access and navigate the health system.10 Indeed, prior studies found that individual SDOH including age, race, education, cognition, health literacy, and social support are associated with mortality after an HF hospitalization,13–17 signaling that such factors may be independent markers of vulnerability after discharge. However, less is known about how the total burden of SDOH within individuals affects mortality after an HF hospitalization.18 In the context of coronary heart disease,19 diabetes mellitus,20 and smoking,21 recent studies have shown that individuals with a greater number of SDOH experience worse outcomes than those with fewer SDOH. Understanding if this holds true in HF is important, as it could have implications for the development of population-based interventions to reduce 90-day mortality following discharge. For example, if higher SDOH burden was associated with post-hospitalization mortality, population managers might develop interventions that target those who are most vulnerable.

To address this gap, we examined associations between multiple within-person SDOH and 90-day mortality among adults hospitalized for HF using the REGARDS (Reasons for Geographic and Racial Differences in Stroke) Study. We hypothesized that individuals with the highest burden of SDOH would have a greater 90-day mortality risk compared with those with fewer SDOH.

METHODS

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

Nonstandard Abbreviations and Acronyms

| Abbreviation | Description |
|--------------|-------------|
| HF           | heart failure |
| SDOH         | social determinants of health |
| REGARDS      | Reasons for Geographic and Racial differences in Stroke Study |
| HPSA         | Health Professional Shortage Area |
| PCS          | Physical Component Summary |
| MCS          | Mental Component Summary |
| HFrEF        | heart failure with reduced ejection fraction |
| LVEF         | left ventricular ejection fraction |
| ICU          | intensive care unit |
| HR           | hazard ratio |

What Is New?

• We estimated the association between multiple within-person social determinants of health (SDOH) and 90-day mortality among adults hospitalized for heart failure.
• Having at least 1 of the 9 SDOH studied here markedly increased the risk of 90-day mortality after an HF hospitalization, but having >1 SDOH was not associated with significantly greater risk than having 1 SDOH in our study population.

What Are the Clinical Implications?

• These observational results suggest that having any of the SDOH assessed herein nearly tripled the risk of 90-day mortality after a hospitalization for HF, independent of a host of other factors.
• These findings expand upon a growing body of research that suggests that SDOH are important determinants of post-discharge outcomes in HF.

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hospice. For reported hospitalizations for a cardiovascular cause, medical records are retrieved for expert adjudication by 2 clinicians to determine the principal contributors to a hospitalization. Adjudicators use a structured form based on prior epidemiology studies; and disagreements are resolved by committee. Adjudication is based on a combination of clinical presentation (including symptoms of dyspnea on exertion, paroxysmal nocturnal dyspnea, night cough; and signs including peripheral edema, jugular venous distention, pulmonary rales, hepatomegaly, abnormal central venous pressure, tachycardia), laboratory evaluation (b-type natriuretic peptide), imaging (chest radiogram with cardiomegaly, pulmonary vascular congestion, or pleural effusion; or cardiac imaging such as echocardiography), and medical treatments (weight loss of ≥4.5 kg in 5 days with diuresis).

The study protocol was reviewed and approved by the University of Alabama at Birmingham Institutional Review Board and the Weill Cornell Medical College Institutional Review Board. All participants provided written informed consent.

**Outcome: Mortality**

The outcome of interest for this study was all-cause 90-day mortality after discharge from an HF hospitalization.

Hospital discharge dates were obtained from Medicare inpatient claims. We obtained mortality data from Medicare enrollment data. Medicare receives information on beneficiary deaths from the Social Security Administration, claims submitted by healthcare providers, and proxy reports.

**Main Exposure(s): Social Determinants of Health**

We used the Healthy People 2020 conceptual framework to guide our analyses, categorizing SDOH into 5 domains: (1) social and community context, (2) education, (3) economic stability, (4) neighborhood and built environment, (5) health and health care (Figure 1). Using this framework, we considered 9 SDOH: black race; social isolation (defined as having 0–1 visits from a family or friend in the past month); social network (defined as whether the participant reported having someone to care for them if ill); low educational attainment (< high school education); low annual household income (<$35 000); living in rural areas (defined as living in an isolated or small rural area based off of Rural Urban Commuting Area Codes); living in a zip code with high poverty (>25% of residence below the federal poverty line); living in a Health Professional Shortage Area (HPSA); and

![Figure 1. Healthy People 2020 Framework’s 5 domains and corresponding social determinants of health (SDOH) studied.](image)
public health infrastructure (assessed using data from the America’s Health Ranking, which ranked states from 1993 to 2002 based on their contribution to lifestyle, access to care, and disability; states that fell into the bottom 20th percentile for their ranking for ≥8 years were considered to have poor public health infrastructure).

All SDOH were assessed at during the REGARDS baseline interview and dichotomized as yes/no. We did not include sex or age as SDOH since they are biologically determined; instead, we accounted for them as covariates in our analyses.

**Covariates**

Covariates were selected using a previously described framework by Calvillo-King et al which conceptualized the impact of social factors on readmission and mortality in HF. Using this framework, we included data on demographics, medical conditions, self-reported health, hospitalization factors, and hospital characteristics. Data were collected from 4 sources: the REGARDS baseline assessment; medical charts from each HF-adjudicated hospitalization; the American Hospital Association annual survey database; and Medicare’s Hospital Compare website.

Demographic and participants’ self-reported health (other than the SDOH previously described) were collected from the REGARDS baseline assessment. Physical and mental health were assessed with the Short Form-12 (SF-12) which captures physical and mental health status through the Physical Component Summary and Mental Component Summary scores. Mental Component Summary and Physical Component Summary scores range from 0 to 100 with higher scores representing better health. Cognition was assessed with the 6-item screener, which is performed annually on REGARDS participants. Cognitive impairment was defined as a 6-item screener score of <5. Of note, the SIS performed before and as close to the adjudicated HF hospitalization as possible, was used. Age at the time of HF hospitalization, medical conditions as assessed by the Charlson comorbidity index, echocardiogram parameters, discharge disposition (home versus nursing home/rehabilitation) and length of stay were abstracted from chart review at the time of the index hospitalization. We defined heart failure with preserved ejection fraction as those with left ventricular ejection fraction (LVEF) >50% or a qualitative description of normal systolic function; and heart failure with reduced ejection fraction as those with an LVEF <50% or a qualitative description of abnormal systolic function. We grouped individuals with LVEF between 40 and 50% with individuals with heart failure with reduced ejection fraction. Hospital-based events including intensive care unit (ICU) stay, involvement of a cardiologist, and all-cause 30-day readmission were also abstracted from charts.

Hospital characteristics were ascertained from the American Hospital Association survey database which contains data on the characteristics of ~6500 hospitals and ~400 health systems across the United States. For this study, we examined hospital size (small hospital size defined as <200 beds) and academic status. Finally, hospital quality was ascertained using the Medicare’s Hospital Compare website which includes publicly available information about the quality of care of over 4000 Medicare-certified hospitals. For this study, we examined hospital rating, which is a summary measure comprised of several different quality metrics used to compare hospitals. Hospital ratings are scored within a range of 1 to 5, with 3 being average and higher scores reflecting higher quality care.

**Statistical Analysis**

We first calculated the frequency and distribution of each candidate SDOH and examined collinearity using phi coefficients. We then examined age-adjusted associations between each candidate SDOH and 90-day mortality, using Cox Proportional Hazards models. Candidate SDOH with statistically significant associations in the minimally adjusted Cox models with P<0.20 were retained for further analysis. Using the retained SDOH to develop an overall SDOH count, we examined cohort characteristics for individuals with 0, 1, and 2 or more SDOH with the Cochran–Mantel–Haenszel test for trend. We calculated incidence rates of 90-day mortality by SDOH count per 1000 person-years. Next, we estimated hazard ratios (HR) and 95% CI in separate Cox models examining the association between the count of SDOH and 90-day mortality. We first examined an age-adjusted association and then sequentially adjusted each model for demographics, medical conditions, physical function, mental function, and cognitive impairment, hospitalization factors, and hospital characteristics, to determine the independent effects of the count of SDOH in fully adjusted models. We performed a trend test by modeling vulnerability count as a continuous variable. We tested for interactions among the individual SDOH that comprised the count, and we tested for interactions by age, sex, and HF subtype using the Wald test. We used Shoenfeld residuals to test the proportionality assumption for Cox models as a whole as well as for the individual exposures of interest. We used multiple imputation by chained equations to minimize bias attributed to missing data. We calculated the average c-statistic for the final model across all 30 imputations.

We used 2-sided hypothesis testing with P<0.05 for all analyses performed. Analyses were conducted in J Am Heart Assoc. 2020;9:e014836. DOI: 10.1161/JAHA.119.014836
RESULTS

Among the 30,239 REGARDS participants, 56 were excluded because of missing baseline information, and 453 were excluded because of lack of follow-up data. Among the 29,730 participants remaining, 28,223 were excluded because they did not have an adjudicated HF hospitalization, and 653 were excluded because they did not have Medicare linkage at the time of the hospitalization. Among the 854 unique participants remaining, 64 were excluded because they died during the hospitalization; 68 were excluded because they were <65 years at the time of discharge; 7 were excluded because they were discharged to hospice. Our post-imputation final analytic cohort for modeling was composed of 690 unique participants who were hospitalized at 440 unique hospitals across the United States (Figure S1). Among them, 92 participants were excluded from the pre-imputation cohort which consisted of 598 unique participants; 690 unique participants who were hospitalized at 440 hospitals. Among the 29,730 participants remaining, 28,223 were excluded because they did not have an adjudicated HF hospitalization, and 653 were excluded because they did not have Medicare linkage at the time of hospitalization. Among the 854 unique participants remaining, 64 were excluded because they died during the hospitalization; 68 were excluded because they were <65 years at the time of discharge; 7 were excluded because they were discharged to hospice. Our post-imputation final analytic cohort for modeling was composed of 690 unique participants who were hospitalized at 440 unique hospitals across the United States (Figure S1). Among them, a total of 79 participants died within 6 months before hospitalization and 90 days following the hospitalization. Finally, 25 were excluded because they did not have continuous Medicare Part A for >65 years at the time of discharge, 7 were excluded because they did not have an adjudicated HF hospitalization, and 653 were excluded because they did not have Medicare linkage at the time of the hospitalization.

Table 1. Age-Adjusted Hazard Ratios for the Effect of Individual SDOH on 90-Day Mortality After Hospital Admission for Heart Failure

| SDOH                                      | HR (95% CI)       | P Value |
|-------------------------------------------|-------------------|---------|
| Black race                                | 1.55 (0.99–2.43)  | 0.05    |
| <High school education                    | 0.95 (0.56–1.61)  | 0.85    |
| Income <$35,000                           | 0.98 (0.60–1.61)  | 0.95    |
| >25% zip code level poverty               | 1.21 (0.72–2.06)  | 0.47    |
| Living in HPSA                            | 1.56 (1.00–2.42)  | 0.05    |
| Poor state public health infrastructure   | 1.19 (0.76–1.86)  | 0.44    |
| Social isolation from friends/family      | 1.30 (0.72–2.37)  | 0.38    |
| No social network                         | 1.60 (0.92–2.79)  | 0.09    |
| Rural residence                           | 1.60 (0.84–3.04)  | 0.15    |

HPSA indicates Health Professional Shortage Area; HR, hazard ratio; and SDOH, social determinants of health.

*Public health infrastructure vulnerability includes 9 states whose ranking had been in the bottom 20% for poor health infrastructure for >80% of the time between 1993 and 2002. The time period reflects the 10 years preceding when Reasons for Geographic and Racial Differences in Strokes study baseline data collection started in 2003.

†Social isolation from friends/family, defined as those who have 0 or 1 friend/family that they have seen in the past month.

‡Social network—defined as no one to care for them if they became ill.

§Rural residence defined as living in an isolated or small rural area. Based in Rural Urban Commuting Area codes.

Selection of Social Determinants of Health

The age-adjusted associations between each of the 9 candidate SDOH and 90-day mortality are shown in Table 1. The SDOH were not found to be collinear (Figure S2). Black race (HR 1.55 [95% CI, 0.99–2.43]), living in an HPSA (1.56 [1.00–2.42]), no social network (having no one to provide care when ill) (1.60 [0.92–2.79]), and rural residence (1.60 [0.84–3.04]) were each associated with 90-day mortality after an HF hospitalization at P<0.20. These 4 SDOH were retained for further analysis in the count of SDOH; participants were then categorized as having 0, 1, and ≥2 of these SDOH. The remaining SDOH were incorporated into models as covariates.

Characteristics of Participants

Characteristics of participants according to SDOH count are shown in Table 2. Before multiple imputation, there were 170 participants with 0 SDOH (28%), 236 with 1 SDOH (39%), and 192 with ≥2 SDOH (32%). Compared with participants with 0 and 1 SDOH, participants with ≥2 SDOH were younger at the time of their HF hospitalization and more likely to be women; have less education and less income; and live in zip codes with high poverty and in areas with poor public health infrastructure. Individuals with a greater number of SDOH also had more comorbidities, and lower self-reported physical and mental health. With respect to hospitalization characteristics, participants with ≥2 SDOH were less likely to undergo coronary revascularization during hospitalization, had longer lengths of stays, often had a cardiologist involved in their care, and were more often discharged to a nursing home compared with those with fewer SDOH. Finally, those with ≥2 SDOH were more likely to be cared for at a teaching hospital.

The highest rates of missing data stemmed from income (11.0%), cognitive impairment (7.0%), and Physical Component Summary/Mental Component Summary (7.0%). All other covariates were missing ≤1%.

SDOH and 90-Day Mortality After HF Hospitalization

The incidence of death at 90 days per 1000 person-years increased with having any SDOH; incidence of 90-day mortality was >3 times as high for those with 1 SDOH (1.85 per 1000 person-years) and ≥2 SDOH (1.77 per 1000 person-years), compared with those with 0 SDOH (0.54 per 1000 person-years). The association between the SDOH count and 90-day mortality is shown in Figure 2. Participants with at least 1 SDOH had greater risk of death at 90 days compared with those with 0 SDOH. The age-adjusted HR
### Table 2. Characteristics From Baseline and Admission by SDOH Count, Among 690 Participants Admitted With Heart Failure in REGARDS

| Characteristics | n   | Total Sample | Total With SDOH | 0 SDOH | 1 SDOH | ≥2 SDOH | P Value* |
|-----------------|-----|--------------|----------------|--------|--------|---------|----------|
| Total           | 690 | 598          | 170            | 236    | 192    |         |          |
| SDOH included in count | |   |            |        |        |         |          |
| Black race      | 690 | 245 (35.5%)  | 598 (39.3%)    | 0 (0.0%)| 92 (39.0%) | 143 (74.5%) |          |
| No social network† | 640 | 85 (13.3%)  | 587 (14.0%)    | 0 (0.0%)| 21 (8.9%) | 61 (33.7%) |          |
| Health Professional Shortage Area | 690 | 300 (43.5%)  | 598 (46.2%)    | 0 (0.0%)| 109 (46.2%) | 167 (87.0%) |          |
| Rural residence‡ | 628 | 64 (10.2%)   | 590 (10.3%)    | 0 (0.0%)| 14 (5.9%) | 47 (25.5%) |          |
| SDOH considered but not used | |   |            |        |        |         |          |
| Low educational attainment | 690 | 162 (23.5%)  | 598 (23.9%)    | 25 (14.7%)| 49 (20.8%) | 69 (35.9%) | <0.001 |
| Income <$35,000 | 598 | 377 (63.0%)  | 524 (64.3%)    | 86 (55.1%)| 121 (60.2%)| 130 (77.8%) | <0.001 |
| Zip code level poverty | 681 | 143 (21.0%)  | 592 (22.5%)    | 13 (7.6%) | 47 (20.3%) | 73 (38.2%) | <0.001 |
| Poor state public health infrastructure§ | 690 | 271 (39.3%)  | 598 (39.3%)    | 58 (34.1%)| 92 (39.0%) | 85 (44.3%) | 0.05     |
| Social isolation∥ | 673 | 88 (13.1%)   | 587 (12.3%)    | 17 (10.1%)| 27 (11.7%) | 28 (14.9%) | 0.16     |
| Demographics | |   |            |        |        |         |          |
| Age (y) at first adjudicated heart failure, median (IQR) | 690 | 76.0 (71.0, 82.0) | 598 (72.0, 82.0) | 76.0 (72.0, 82.0) | 76.0 (72.0, 82.0) | 74.0 (70.0, 81.0) | 0.02 |
| Female sex | 690 | 306 (44.3%)  | 598 (44.1%)    | 264 (44.1%)| 61 (35.9%) | 98 (41.5%) | 105 (54.7%) | <0.001 |
| Region of residence | 690 | 598          | 598 (35.9%)    | 98 (41.5%)| 98 (41.5%) | 105 (54.7%) | <0.001 |
| Stroke belt | 690 | 250 (36.2%)  | 598 (36.5%)    | 218 (36.5%)| 64 (37.6%) | 78 (33.1%) | 76 (39.6%) | 0.05     |
| Stroke buckle | 690 | 152 (22.0%)  | 598 (21.1%)    | 126 (21.1%)| 48 (28.2%) | 59 (25.0%) | 19 (9.9%)  | 0.05     |
| Non-stroke belt | 690 | 288 (41.7%)  | 598 (42.5%)    | 254 (42.5%)| 58 (34.1%) | 99 (41.9%) | 97 (50.5%) | 0.05     |
| Medical conditions and health behaviors | |   |            |        |        |         |          |
| Current smoking | 690 | 66 (9.6%)    | 598 (9.7%)     | 58 (9.7%) | 13 (7.6%) | 25 (10.6%) | 20 (10.4%) | 0.387 |
| Charlson Comorbidity Index, median (IQR) | 687 | 4.0 (3.0, 5.0) | 595 (3.0, 5.0) | 4.0 (3.0, 5.0) | 3.0 (2.0, 4.0) | 4.0 (3.0, 5.0) | <0.001 |
| Physical and mental functioning | |   |            |        |        |         |          |
| Impaired cognition† | 634 | 113 (17.8%)  | 550 (19.1%)    | 105 (15.1%)| 24 (15.1%) | 46 (21.3%) | 35 (20.0%) | 0.27     |
| PCS—physical health, median (IQR) | 643 | 41.7 (31.6, 49.9) | 559 (41.9, 49.9) | 45.6 (34.9, 52.4) | 41.1 (31.3, 49.8) | 40.9 (31.6, 47.9) | <0.01 |
| MCS—mental health, median (IQR) | 643 | 56.7 (49.5, 59.9) | 559 (49.7, 60.0) | 57.8 (53.2, 60.2) | 57.1 (50.7, 60.2) | 54.4 (45.3, 59.9) | <0.0001 |

(Continued)
Table 2. Continued

| Characteristics                                      | n    | Total Sample | n    | Total With SDOH Data | 0 SDOH | 1 SDOH | ≥2 SDOH | P Value* |
|-----------------------------------------------------|------|--------------|------|----------------------|--------|--------|---------|----------|
| ICU stay during hospitalization                      | 690  | 145 (21.0%)  | 598  | 125 (20.9%)          | 35 (20.6%) | 48 (20.3%) | 42 (21.9%) | 0.76     |
| MI during hospitalization                            | 690  | 111 (16.1%)  | 598  | 97 (16.2%)           | 26 (15.3%) | 46 (19.5%) | 25 (13.0%) | 0.51     |
| Revascularization during hospitalization             | 690  | 79 (11.4%)   | 598  | 64 (10.7%)           | 23 (13.5%) | 29 (12.3%) | 12 (6.3%)  | 0.02     |
| Consult with Cardiologist                           | 690  | 211 (30.6%)  | 598  | 184 (30.8%)          | 43 (25.3%) | 75 (31.8%) | 66 (34.4%) | 0.06     |
| Discharged to nursing home                          | 680  | 85 (12.5%)   | 590  | 74 (12.5%)           | 14 (8.4%)  | 28 (12.0%) | 32 (16.8%) | 0.02     |
| Length of stay, median (IQR)                        | 690  | 5.0 (3.0, 8.0)| 598  | 5.0 (3.0, 8.0)       | 4.0 (3.0, 7.0) | 5.0 (3.0, 8.0) | 5.0 (3.0, 8.0) | 0.03     |
| 30-d readmission                                    | 690  | 155 (22.5%)  | 598  | 137 (22.9%)          | 30 (17.6%) | 57 (24.2%) | 50 (26.0%) | 0.14     |
| Ejection fraction ≤40                               | 509  | 233 (45.8%)  | 438  | 202 (46.1%)          | 60 (47.2%) | 84 (48.0%) | 58 (42.7%) | 0.62     |
| Ejection fraction >50                               | 509  | 280 (55.0%)  | 438  | 244 (55.7%)          | 74 (58.3%) | 103 (55.9%) | 67 (49.3%) | 0.14     |

Hospital characteristics

| Bed size, median (IQR)                               | 688  | 348.5 (201.0, 564.0) | 596  | 344.5 (199.5, 547.0) | 356.0 (203.0, 572.0) | 334.0 (220.5, 576.0) | 346.0 (180.0, 539.0) | 0.33     |
| Bed size <200                                       | 688  | 169 (24.5%)          | 596  | 149 (24.9%)          | 41 (24.1%)  | 54 (22.9%) | 54 (28.1%) | 0.36     |
| Teaching status                                     | 688  | 324 (47.1%)          | 596  | 280 (47.0%)          | 73 (43.2%)  | 109 (46.2%) | 98 (51.3%) | 0.12     |
| Hospital overall quality rating, mean (SD)          | 648  | 2.9 (0.9)            | 566  | 2.9 (0.9)            | 3.0 (0.8)   | 2.9 (1.0)  | 2.8 (1.0)  | 0.15     |

Note: Some participants missing vulnerability in Table 1. These participants where imputed to modeling. HPSA indicates Health Professional Shortage Area; HR, hazard ratio; ICU, intensive care unit; IQR, interquartile range; MCS, Mental Component Summary score; PCS, Physical Component Summary score; and SDOH, social determinants of health.

*Test of Spearman rank coefficient for continuous characteristic and Mantel–Haenszel for categorical characteristics.

Social determinants of health vary by communities.

†Social network—no one to provide care—defined as participants who reported they had no one to care for them if they became ill.

‡Rural residence defined as living in an isolated or small rural area. Based on Rural Urban Commuting Area codes.

§Public health infrastructure includes 9 states whose ranking had been in the bottom 20% for poor health infrastructure for ≥80% of the time between 1993 and 2002. The period reflects the 10 years preceding when REGARDS (Reasons for Geographic and Racial Differences in Strokes) study baseline data collection started in 2003.

∥Social isolation from friends/family defined as those who have 0 or 1 friend/family that they have seen in the past month.

¶Cognitive impairment defined as a score ≤4 on 6-item screener.
comparing 1 to 0 SDOH was 2.89 (1.46–5.72) and the age-adjusted HR comparing ≥2 to 0 was 3.06 (1.51–6.19). These associations remained present after adjustment for demographic characteristics, medical comorbidities, self-reported mental and physical health, hospitalization factors, and hospital characteristics. Compared with having 0 SDOH, having 1 SDOH was associated with a fully adjusted HR of 2.78 (1.37–5.62) and having ≥2 SDOH was associated with a fully adjusted HR of 2.57 (1.19–5.54) (Table 3). We examined interactions between race and the 3 other variables that comprised the SDOH count (HPSA, rural residence, and social network); no significant interactions were observed (P<0.10). We also examined effect modification by testing interactions by age, sex, and HF subtype. Again, no significant interactions were observed (P<0.10).

**DISCUSSION**

In this prospective cohort study of Medicare beneficiaries hospitalized for HF, we observed that having at least one SDOH significantly increased participants’ risk of 90-day mortality. While we expected to find that a greater number of within-person SDOH would be associated with a greater risk of death at 90 days, we found that having any SDOH was associated with nearly 3 times the risk of 90-day mortality, compared with those without SDOH. This association persisted after adjustment for a host of demographic, clinical, and hospitalization variables known to be associated with poor outcomes among older adults after an HF hospitalization. Taken together, our findings suggest that having at least 1 of these SDOH—being black, having no one to provide care for you when ill, living in an HPSA, or living

| Groups          | N^  | No. of Events | Incidence Rate* (95% CI) | HR (95% CI) | p-value |
|-----------------|-----|---------------|--------------------------|-------------|---------|
| Age Adjusted    |     |               |                          |             |         |
| 0 SDOH          | 170 | 8             | 0.54 (0.27, 1.08)        | 1           |         |
| 1 SDOH          | 236 | 36            | 1.85 (1.34, 2.57)        | 2.89 (1.46–5.72) | 0.002   |
| ≥2 SDOH         | 192 | 26            | 1.77 (1.22, 2.57)        | 3.06 (1.51–6.19) | 0.002   |
| Fully Adjusted  |     |               |                          |             |         |
| 0 SDOH          | 170 | 8             | 0.54 (0.27, 1.08)        | 1           |         |
| 1 SDOH          | 236 | 36            | 1.85 (1.34, 2.57)        | 2.78 (1.37–5.62) | 0.005   |
| ≥2 SDOH         | 192 | 26            | 1.77 (1.22, 2.57)        | 2.57 (1.19–5.54) | 0.023   |

**Figure 2.** Age- and fully adjusted hazard ratios for SDOH count and 90-day mortality.

^Numbers are from the pre-imputation data set. Estimates computed from multiple imputation data set; *Incident rates per 1000 person-years. HR indicates hazard ratio; REGARDS, Reasons for Geographic and Racial Differences in Strokes; and SDOH, social determinants of health.

**Table 3.** Effect of SDOH Count on 90-Day Mortality After Hospital Admission for Heart Failure in REGARDS

| Models                | 1 SDOH                      | ≥2 SDOH                     | P for Trend |
|-----------------------|-----------------------------|-----------------------------|-------------|
|                       | HR (95% CI)                 | HR (95% CI)                 |             |
| Age-adjusted model    | 2.89 (1.46–5.72)            | 3.06 (1.51–6.19)            | 0.002       |
| Model 1               | 2.98 (1.50–5.92)            | 3.29 (1.56–6.93)            | 0.002       |
| Model 2               | 2.98 (1.49–5.93)            | 3.26 (1.55–6.86)            | 0.002       |
| Model 3               | 2.96 (1.48–5.92)            | 3.40 (1.60–7.18)            | 0.001       |
| Model 4               | 2.80 (1.38–5.67)            | 2.58 (1.20–5.57)            | 0.022       |
| Model 5               | 2.78 (1.37–5.62)            | 2.57 (1.19–5.54)            | 0.023       |

Note: 0 Social determinants of health is the referent group. Model 1: Demographics (age, sex, income, education, zip code level poverty, poor public health infrastructure). Model 2: Model 1+Medical conditions and cardiovascular disease Risk Factors (Charlson Comorbidity Index, current smoking). Model 3: Model 2+Self-reported health and cognition (Physical Component Summary Score, Mental Component Summary Score, impaired cognition). Model 4: Model 3+Hospitalization characteristics and transitions in care (revascularization during hospitalization, discharge from nursing home, length of stay, intensive care unit stay during hospitalization, consult with cardiologist, 30-day readmission). Model 5: Model 4+Hospital characteristics (teaching status). HPSA indicates Health Professional Shortage Area; HR, hazard ratio; REGARDS, Reasons for Geographic and Racial Differences in Strokes; and SDOH, social determinants of health.
in a rural area—may serve as an important risk indicator for death in the post-discharge period.

While prior studies examined the individual effect of various SDOH on mortality among patients hospitalized for HF, our study is the first to examine the effect of multiple within-person SDOH on mortality. A systematic review by Calvillo-King (2013) found individual SDOHs such as education, income, race, and social support were independently associated with short-term mortality after an HF hospitalization. More recently, studies have shown that health literacy and region of residence (urban versus rural) are also associated with post-hospitalization mortality. Rather than examining individual constituents, our study examined the effect of the total burden of SDOH within individuals. Indeed, 71.0% of our cohort had ≥1 SDOH. By examining a count of SDOH, our study extends prior research, offering a broader look at how social disadvantage affects mortality post-HF hospitalization.

The mechanistic pathways through which SDOH would lead to increased risk of 90-day mortality after an HF hospitalization remain unclear. However, several plausible mechanisms exist. At the biologic level, living with SDOH can result in toxic levels of chronic stress that can lead to a sustained allostatic stress response. Such a response can lead to dysregulation of the hypothalamic pituitary adrenal axis and autonomic nervous system leading to endothelial dysfunction, an upregulation of cytokine expression, and maladaptive hemodynamic changes that contribute to adverse outcomes among adults with prevalent HF. Behavioral mechanisms are likely to play a role here as well. HF requires substantial self-care and many older adults hospitalized for HF have significant functional, cognitive, and/or sensory deficits. The post-hospitalization period, a time when patients are asked to perform many HF self-care tasks, take new medications, and follow-up with doctors, can be particularly challenging for HF patients, especially those that lack social support or access to community or healthcare resources. A lack of social support in particular (one of the main SDOH in our count) can adversely impact patients’ psychological well-being as well as alter their capacity for HF self-care, which in turn, result in adverse post-hospitalization outcomes; and living in an HPSA or rural area may create challenges with regard to patients’ ability to seek and receive appropriate care following discharge, which could again have downstream effects on health outcomes.

Yet, despite a rationale for multiple within-person SDOH incrementally increasing risk for post-hospitalization mortality, we found that the risk of just a single SDOH increased risk of mortality by 3 and that risk for mortality was not increased further in the setting of more SDOH. These data indicate that additional vulnerabilities, at least among Medicare beneficiaries, may be less important once you already have at least 1. Based on these findings, we suspect that future efforts to risk stratify older adults following an HF hospitalization should cast a broader net and target individuals with just 1 of these SDOH.

Incorporating SDOH into risk prediction tools to improve post-hospitalization outcomes in HF could be helpful. While some such tools exist, most have limited predictive value which likely relates to the observation that they often rely exclusively on physiologic data, failing to account for SDOH. Although our findings should be confirmed in other larger cohorts, the addition of SDOH to existing risk prediction tools may be warranted. This approach has proven effective with respect to estimating readmission risk after an HF hospitalization; a recent study by Joynt Maddox et al demonstrated that accounting for SDOH such as poverty, disability, housing instability, residence in a disadvantaged neighborhood, and hospital population from a disadvantaged neighborhood significantly impacted readmission rates and penalties associated with Medicare’s Hospital Readmissions Reduction Program among safety net hospitals. Although we studied a different group of SDOH here, our study adds to the growing body of evidence that population health managers should consider assessing SDOH profiles to more accurately identify which patients are the most vulnerable after discharge.

Our findings also suggest that interventions aimed at reducing post-discharge mortality after an HF hospitalization are likely to require multilevel strategies. Increased awareness on the SDOH by those involved in the hospital-to-home transition (clinicians, nurses, care managers, and social workers) is needed to screen for these factors and potentially intervene. For example, if a patient admitted for HF lives in a rural area and lacks social support, efforts to set up home care or community assistance before discharge may be beneficial. Interventions such as telehealth could potentially overcome access barriers in HPSA and rural areas. Future studies which rigorously assess the effectiveness of interventions that address SDOH on post-discharge outcomes in HF, may be warranted.

Strengths and Limitations

Our study has several strengths. First, it includes a national, biracial sample with rigorously collected data and adjudicated HF hospitalizations. In addition to studying demographic and health-related characteristics of participants, we were able to assess characteristics of the HF hospitalization and the hospital to which patients were admitted.
A few limitations should also be noted. While we assessed SDOH from each domain of the Healthy People 2020 Framework, there are SDOH that we were unable to assess here including neighborhood and physical environment (such as the availability of food and housing, transportation, and safety), and racial discrimination. We also were unable to assess post-discharge processes like prescription fills and follow-up appointments, which may affect post-discharge mortality. Another limitation is the relatively modest sample size, which may have limited our ability to test for additional interactions. Finally, we used the baseline REGARDS interview to assess the majority of SDOH, which may have occurred several years before the adjudicated HF hospitalization. This limitation may be mitigated by our findings, which suggest that SDOH—even when captured years prior—are strongly associated with future outcomes, thus adding to the mounting evidence that factors upstream of the HF hospitalization be considered.

CONCLUSIONS

The results of this study suggest that having any of an individuals’ SDOH assessed herein nearly tripled the risk of 90-day mortality after a hospitalization for HF, independent of a host of covariates representing individual characteristics, details of the hospitalization, and characteristics of the hospital. These findings expand upon a growing body of research that suggests SDOH are important determinants of post-discharge outcomes in HF. Assessing SDOH may serve as a new marker for identifying and intervening upon the most vulnerable HF patients in the post-discharge period.

ARTICLE INFORMATION

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Supplemental Material

Figures S1 to S2

REFERENCES

1. Yancy CW, Jessup M, Bozkurt B, Butler J, Casey DE Jr, Drazner MH, Fonarow GC, Geraci SA, Horwich T, Januzzi JL, et al. 2013 ACCF/AHA guideline for the management of heart failure: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. Circulation. 2013;128:e240–e327.

2. Gheorghiade M, Vaduganathan M, Fonarow GC, Bonow RO. Rehospitalization for heart failure: problems and perspectives. J Am Coll Cardiol. 2013;61:391–403.

3. Chioncel O, Collins SP, Greene SJ, Pang PS, Ambrosy AP, Antohi EL, Vaduganathan M, Butler J, Gheorghiade M. Predictors of post-discharge mortality among patients hospitalized for acute heart failure. Card Fail Rev. 2017;3:122–129.

4. Cheng RK, Cox M, Neely ML, Heidenreich PA, Bhatt DL, Eapen ZJ, Hernandez AF, Butler J, Yancy CW, Fonarow GC. Outcomes in patients with heart failure with preserved, borderline, and reduced ejection fraction in the Medicare population. Am Heart J. 2014;168:721–730.

5. Dharmarajan K, Hsieh AF, Kulkarni VT, Lin Z, Ross JS, Horwitz LI, Kim N, Suter LG, Lin H, Normand S-LT. Trajectories of risk after hospitalization for heart failure, acute myocardial infarction, or pneumonia: retrospective cohort study. BMJ. 2015;350:h411.

6. Shah KS, Xu H, Matsouaka RA, Bhatt DL, Heidenreich PA, Hernandez AF, Devore AD, Yancy CW, Fonarow GC. Heart failure with preserved, borderline, and reduced ejection fraction: 5-year outcomes. J Am Coll Cardiol. 2017;70:2476–2486.

7. Whellan DJ, Cox M, Hernandez AF, Heidenreich PA, Curtis LH, Peterson ED, Fonarow GC. Utilization of hospice and predicted mortality risk among older patients hospitalized with heart failure: findings from GWTG-HF. J Card Fail. 2012;18:471–477.

8. O’Connor M, Murtaugh CM, Shah S, Barron-Vaya Y, Bowles KH, Peng TR, Zhu CW, Feldman PH. Patient characteristics predicting readmission among individuals hospitalized for heart failure. Med Care Res Rev. 2016;73:3–40.

9. Davison BA, Metra M, Senger S, Edwards C, Milo O, Bloomfield DM, Cleland JG, Dittrich HC, Givertz MM, O’Connor CM, et al. Patient journey after admission for acute heart failure: length of stay, 30-day readmission and 90-day mortality. Eur J Heart Fail. 2016;18:1041–1050.

10. Meyers AG, Salanitro A, Wallston KA, Cawthon C, Vasilevskis EE, Goggins KM, Davis CM, Rothman RL, Gastel LD, Donato KM, et al. Determinants of health after hospital discharge: rationale and design of the Vanderbilt Inpatient Cohort Study (VICS). BMC Health Serv Res. 2014;14:10.

11. Hersh AM, Masoud FA, Allen LA. Postdischarge environment following heart failure hospitalization: expanding the view of hospital readmission. J Am Heart Assoc. 2013;2:e000116. DOI: 10.1161/JAHA.113.000116.

12. Daniel H, Bornstein SS, Kane GC. Addressing social determinants to improve patient care and promote health equity: an American College of Physicians position paper. Ann Intern Med. 2018;168:577–578.

13. Calviño-King L, Arnold D, Eubank KJ, Lo M, Yuruyongying P, Stiegitz H, Halm EA. Impact of social factors on risk of readmission or mortality in pneumonia and heart failure: systematic review. J Gen Intern Med. 2013;28:269–282.

14. McNaughton CD, Cawthon C, Kripalani S, Liu D, Storrow AB, Roumie CL. Health literacy and mortality: a cohort study of patients hospitalized...
for acute heart failure. J Am Heart Assoc. 2015;4:e001799. DOI: 10.1161/JAHA.115.001799.

15. Gordon HS, Nowlin PR, Maynard D, Berbaum ML, Deswal A. Mortality after hospitalization for heart failure in blacks compared to whites. Am J Cardiol. 2010;105:694–700.

16. Krumholz HM, Butler J, Miller J, Vaccarino V, Williams CS, Mendes de Leon CF, Seeman TE, Kasi SV, Berkman LF. Prognostic importance of emotional support for elderly patients hospitalized with heart failure. Circulation. 1998;97:958–964.

17. Rodriguez-Artalejo F, Guallar-Castillon P, Herrera MC, Otero CM, Chiva MO, Ochoa CC, Banegas JR, Pascual CR. Social network as a predictor of hospital readmission and mortality among older patients with heart failure. J Card Fail. 2006;12:621–627.

18. McGovern L, Miller G, Hughes-Cromwick P. Health policy brief: the relative contribution of multiple determinants to health outcomes, health affairs. 2014.

19. Schroff P, Gamboa CM, Durant RW, Oikeh A, Richman JS, Safford MM. Vulnerabilities to health disparities and stratification in the REGARDS (Reasons for Geographic and Racial Differences in Stroke) study. J Am Heart Assoc. 2017;6:e005449. DOI: 10.1161/JAHA.116.005449.

20. Echouffo-Tcheugui JB, Caleyachetty R, Muennig PA, Narayan K, Golden SH. Cumulative social risk and type 2 diabetes in adults: the National Health and Nutrition Examination Survey (NHANES) 1999 to 2006. Eur J Prev Cardiol. 2016;23:1282–1288.

21. Leventhal AM, Bello MS, Galstyan E, Higgins ST, Barrington-Trimis JL. Association of cumulative socioeconomic and health-related disadvantage with disparities in smoking prevalence in the United States, 2008 to 2017. JAMA Intern Med. 2019;179:777–785.

22. Howard VJ, Cushman M, Pulley L, Gomez CR, Go RC, Prineas RJ, Graham A, Moy CS, Howard G. The reasons for geographic and racial differences in stroke study: objectives and design. Neuroepidemiology. 2005;25:135–143.

23. Healthy People 2020. Available at: https://www.healthypeople.gov/2020/topics-objectives/topic/social-determinants-of-health. Accessed June 21, 2018.

24. Social Determinants of Health. Available at: https://www.healthypeople.gov/2020/topics-objectives/topic/social-determinants-of-health. Accessed June 21, 2018.

25. American’s Health Rankings. Available at: https://www.americanhealthrankings.org/. Accessed June 5, 2019.

26. AHA Annual Survey Database. Available at: https://www.aha.org/data-insights/aha-data-products. Accessed June 20, 2018.

27. Hospital Compare. Available at: https://www.cms.gov/Medicare/Quality- Initiatives-Patient-Assessments-Instruments/HospitalQualityInitiatives/HospitalCompare. Accessed June 20, 2018.

28. Ware J Jr, Kosinski M, Keller SD. A 12-Item Short-Form Health Survey: construction of scales and preliminary tests of reliability and validity. Med Care. 1996;34:220–233.

29. Callahan CM, Unutzer J, Hsu HL, Perkins AJ, Hendrie HC. Six-item screener to identify cognitive impairment among potential subjects for clinical research. Med Care. 2002;40:771–781.

30. Yancy CW, Jessup M, Bozkurt B, Butler J, Casey DE Jr, Drazner MH, Fonarow GC, Geraci SA, Horwich T, Januzzi JL, et al. 2013 ACCF/AHA guideline for the management of heart failure: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol. 2013;62:e147–e239.

31. Butler J, Anker SD, Packard M. Redefining heart failure with a reduced ejection fraction. JAMA. 2019. DOI: 10.1001/jama.2019.15600. [Epub ahead of print].

32. Thiese MS, Ronna B, Ott U. P value interpretations and considerations. J Thorac Dis. 2016;8:E392–E391.

33. Sterne JAG, Smith GD. Sifting the evidence—what’s wrong with significance tests? BMJ. 2001;322:226–231.

34. Gamble JM, Uehrich DT, Ezekowitz KA, Kaul P, Quan H, McAlister FA. Patterns of care and outcomes differ for urban versus rural patients with newly diagnosed heart failure, even in a universal healthcare system. Circ Heart Fail. 2011;4:317–323.

35. Havranek EP, Mujahid MS, Ban DA, Blair IV, Cohen MS, Cruz-Flores S, Davey-Smith G, Demmings-Heniford CR, Lauer MS, Lockwood DW, et al. Social determinants of risk and outcomes for cardiovascular disease: a scientific statement from the American Heart Association. Circulation. 2015;132:873–898.

36. Gruenewald TL, Karlamangla AS, Hu P, Stein-Merkin S, Crandall C, Koretz B, Seeman TE. History of socioeconomic disadvantage and allostatic load in later life. Soc Sci Med. 2012;74:75–83.

37. McEwen BS, Gianaros PJ. Central role of the brain in stress and adaptation: links to socioeconomic status, health, and disease. Ann NY Acad Sci. 2010;1186:190–222.

38. Szanton SL, Gill JM, Allen JK. Allostatic load: a mechanism of socioeconomic health disparities? Biol Res Nurs. 2005;7:7–15.

39. Riegel B, Moser DK, Anker SD, Appel LJ, Dunbar SR, Grady KL, Gurvitz MZ, Havranek EP, Lee CS, Lindenfeld J, et al. State of the science: promoting self-care in persons with heart failure: a scientific statement from the American Heart Association. Circulation. 2009;120:1141–1163.

40. Gorodeski EZ, Goyal P, Hummel SL, Krishnaswami A, Goodlin SJ, Hart LL, Forman DE, Wenger NK, Kirkpatrick JN, Alexander KP. Domain management approach to heart failure in the geriatric patient: present and future. J Am Coll Cardiol. 2018;71:1921–1936.

41. Davidson JA, Truong TTN, Towe VR, Kerins G, Chaudhry SI. Cognitive impairment in older adults with heart failure: prevalence, documentation, and impact on outcomes. J Am Med. 2013;126:120–126.

42. Sterling MR, Safford MM, Goggins K, Nwosu SK, Schildcrout JS, Wallston KA, Mixon AS, Rothman RL, Kripalani S. Numeracy, health literacy, cognition, and 30-day readmissions among patients with heart failure. J Hosp Med. 2018;13:145–151.

43. Sterling MR, Lin FR, Jannat-Khah DP, Goman AM, Echeverria SE, Safford MM. Hearing loss among older adults with heart failure in the United States: data from the National Health and Nutrition Examination Survey. JAMA Otolaryngol Head Neck Surg. 2018;144:273–275.

44. Buck HG, Hankness K, Wion R, Carroll SL, Cosman T, Kaasaalainen A, Sparr M, Pyorwarchock J, McCollinn M, O’Keefe-McCarthy S, Sherifali D, et al. Caregivers’ contributions to heart failure self-care: a systematic review. Eur J Cardiovasc Nurs. 2015;14:79–89.

45. Riegel B, Dickson VV, Faulkner KM. The situation-specific theory of heart failure self-care: revised and updated. J Cardiovasc Nurs. 2016;31:226–235.

46. Cene CW, Loehr L, Lin FC, Hammond WP, Foraker RE, Rose K, Mosley T, Corbie-Smith G. Social isolation, vital exhaustion, and incident heart failure: findings from the Atherosclerosis Risk in Communities Study. Eur J Heart Fail. 2012;14:748–753.

47. Brown TM, Parmar G, Durant RW, Halanych JH, Hovater M, Muntner P, Prineas RJ, Roth DL, Samdarshi TE, Safford MM. Health Professional Shortage Areas, insurance status, and cardiovascular disease prevention in the Reasons for Geographic and Racial Differences in Stroke (REGARDS) Study. J Health Care Poor Underserved. 2011;22:1179–1189.

48. Lagu T, Pekow PS, Shieh MS, Stefan M, Pack QR, Kashef MA, Atreya AR, Valania G, Slausky WT, Lindenauer PK. Validation and comparison of seven mortality prediction models for hospitalized patients with acute decompensated heart failure. Circ Heart Fail. 2016;9:e002912.

49. Fonarow GC, Abraham WT, Albert NM, Strugh WG, Gheorghiade M, Greenberg BH, O’Connor CM, Pieper K, Sun JL, Yancy C, et al. Association between performance measures and clinical outcomes for patients hospitalized with heart failure. JAMA. 2007;297:61–70.

50. Peterson PN, Rumsfeld JS, Liang L, Albert NM, Hernandez AF, Maron DJ, Nagasako EM, Nerenz DR. Adjusting for social risk factors impacts performance and penalties in the hospital readmissions reduction program. Health Serv Res. 2019;54:327–336.

51. Johnston KJ, Wen H, Schootman M, Joynt Maddox KE. Association of patient social, cognitive, and functional risk factors with preventable hospitalizations: implications for physician value-based payment. J Gen Intern Med. 2019;34:1645–1652.

52. Bultron de la Vega P, Bosi L, Sprague Martinez L, Bovell-Ammon A, Garg A, James T, Ewen AM, Stack M, DeCarvalho H, Sandel M, et al. Implementing an EHR-based screening and referral system to address social determinants of health in primary care. Med Care. 2019;57:133–139.

53. Castrucci B, Auerbach J. Meeting Individual Social Needs Falls Short of Addressing Social Determinants Of Health | Health Affairs. 2019;53:25–32.

54. Joynt Maddox KE, Reidhead M, Hu J, Kind AJH, Zaslavsky AM, Nagasako EM, Nerenz DR. Adjusting for social risk factors impacts performance and penalties in the hospital readmissions reduction program. Health Serv Res. 2019;54:327–336.
SUPPLEMENTAL MATERIAL
Figure S1. Exclusion Cascade for The Effect of SDOH on 90-Day Mortality after HF Hospitalization in REGARDS.

REGARDS sample
n = 30,239 unique participants

n = 29,730 unique participants

n = 1507 unique participants

n = 854 unique participants

n = 790 unique participants

n = 715 unique participants

n = 690 unique participants (post-imputation sample; final analytic cohort)

n = 558 unique participants (pre-imputation sample)

• No follow-up (n=453)
• Missing baseline survey (n=56)

• Participants without an adjudicated heart failure hospitalization*

• No linkage to Medicare (n=653)

• Death during hospitalization (n=64)

• Age < 65 years at discharge (n=68)
• Without continuous Medicare Part A for 90 days following hospitalization (n=7)

• Discharged with hospice referral (n=25)

• Missing information on SDOH (n=92)

Abbreviations: REGARDS: Reasons for geographic and racial differences in stroke
*First adjudicated heart failure hospitalization in REGARDS may include participants with evidence of prior heart failure
Figure S2. Phi correlation matrix among selected SDOH.

SDOH – Social determinants of health; HPSA- Healthcare Provider Shortage Area; isolation: not having someone to care for them if ill; rural area defined as living in an isolated or small rural area, based off of Rural Urban Commuting Area codes; living in a Health Professional Shortage Area (HPSA).

Phi coefficients range from -1 to 1, with -1.0 to -0.7 indicating a strong-negative correlation; -0.7 to -0.3, indicating a weak-negative correlation; -0.3 to 0.3, indicating very little or no correlation; 0.3 to 0.7, indicating a weak-positive correlation; 0.7 to 1.0, indicating a strong-positive correlation.