


ORIGINAL RESEARCH

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 individuals' 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

Heat 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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CLINICAL PERSPECTIVE

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.

Nonstandard Abbreviations and Acronyms

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
HFpEF	heart failure with preserved ejection fraction
HfrEF	heart failure with reduced ejection fraction
LVEF	left ventricular ejection fraction
ICU	intensive care unit
HR	hazard ratio

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.

Study Population

Details of the REGARDS study have been described previously.²² Briefly, the REGARDS study is a national, prospective, observational cohort of 30 239 community-dwelling black and white men and women aged ≥ 45 years from all 48 contiguous states in the United States and the District of Columbia. The REGARDS study was initially designed to investigate racial and geographic disparities in stroke mortality. Participants were recruited from 2003 to 2007 with ongoing follow-up.²² Participants were recruited through a mailing followed by telephone contact. Black adults and residents of the Stroke Belt, an area in the southeastern United States with high stroke mortality, were oversampled by design. Participants completed a telephone interview ascertaining medical history followed by an in-home examination assessing blood pressure levels, height and weight, obtaining ECGs, anthropomorphic measures, and blood and urine samples along with a medication inventory. At 6-month intervals, participants are contacted by phone to ask about general health status and potential study end points such as hospitalizations. For this study, we included REGARDS participants aged ≥ 65 years with a first adjudicated HF-hospitalization between 2003 and 2014 who had continuous Medicare Part A for 6 months before their hospitalization and for the 90 days following their hospitalization. We excluded individuals discharged to

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).^{23,24} 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

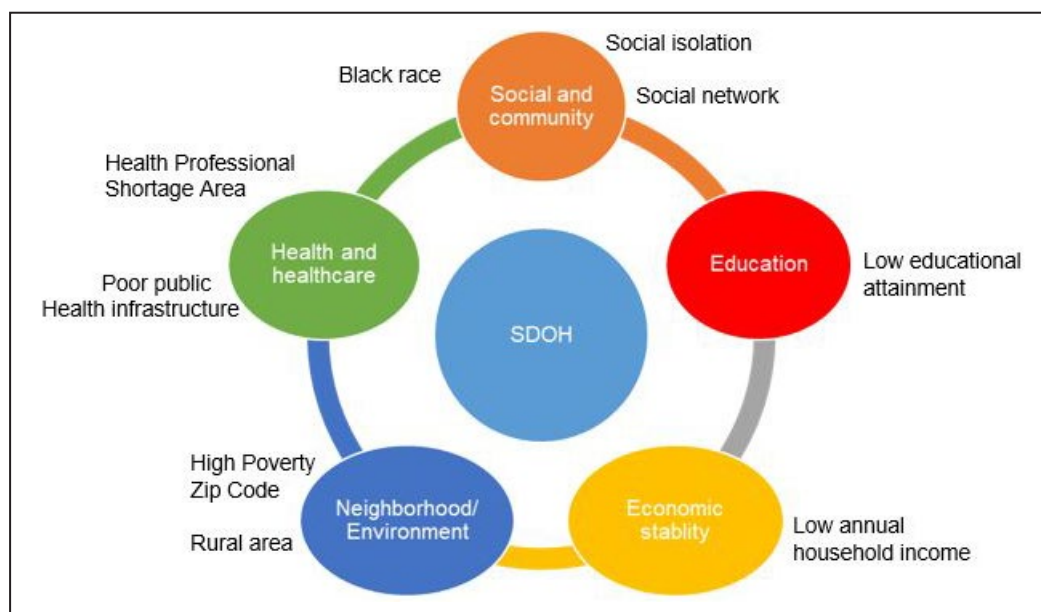


Figure 1. Healthy People 2020 Framework's 5 domains and corresponding social determinants of health (SDOH) studied.

Adapted from *Social Determinants of Health*.²⁴ Black race, social isolation (having 0–1 visits from a family or friend in the past month); social network (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 a rural area (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, living in a state with poor public infrastructure (assessed using data from the America's Health Ranking; states that fell into the bottom 20th percentile for their ranking for ≥ 8 years were considered to have poor public health infrastructure).

public health infrastructure (assessed using data from the America's Health Ranking,²⁵ 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 al¹³ 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 database²⁶; and Medicare's Hospital Compare website.²⁷

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.²⁸ 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 .²⁹ 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.³⁰ We grouped individuals with LVEF between 40 and 50% with individuals with heart failure with reduced ejection fraction.³¹ 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.²⁶ 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.²⁷ 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.^{32,33} 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 Schoenfeld 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

SAS software version 9.4 (SAS Institute, Cary, NC) and Stata 14 (StataCorp, College Station, TX).

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 did not have continuous Medicare Part A for 6 months before hospitalization and 90 days following the hospitalization. Finally, 25 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 90 days (11.0%). For descriptive tables, we used the pre-imputation cohort which consisted of 598 unique participants; 92 participants were excluded from the final analytic cohort (13.0%) who were missing data on SDOH count at baseline (Figure S1).

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	n	Total With SDOH Data	0 SDOH	1 SDOH	≥2 SDOH	P Value*
n		690		598	170	236	192	
SDOH included in count								
Black race	690	245 (35.5%)	598	235 (39.3%)	0 (0.0%)	92 (39.0%)	143 (74.5%)	
No social network†	640	85 (13.3%)	587	82 (14.0%)	0 (0.0%)	21 (8.9%)	61 (33.7%)	
Health Professional Shortage Area	690	300 (43.5%)	598	276 (46.2%)	0 (0.0%)	109 (46.2%)	167 (87.0%)	
Rural residence‡	628	64 (10.2%)	590	61 (10.3%)	0 (0.0%)	14 (5.9%)	47 (25.5%)	
SDOH considered but not used								
Low educational attainment	690	162 (23.5%)	598	143 (23.9%)	25 (14.7%)	49 (20.8%)	69 (35.9%)	<0.001
Income <\$35 000	598	377 (63.0%)	524	337 (64.3%)	86 (55.1%)	121 (60.2%)	130 (77.8%)	<0.001
Zip code level poverty	681	143 (21.0%)	592	133 (22.5%)	13 (7.6%)	47 (20.3%)	73 (38.2%)	<0.001
Poor state public health infrastructure§	690	271 (39.3%)	598	235 (39.3%)	58 (34.1%)	92 (39.0%)	85 (44.3%)	0.05
Social isolation¶	673	88 (13.1%)	587	72 (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	76.0 (71.0, 82.0)	77.0 (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	264 (44.1%)	61 (35.9%)	98 (41.5%)	105 (54.7%)	<0.001
Region of residence	690		598					<0.001
Stroke belt	690	250 (36.2%)	598	218 (36.5%)	64 (37.6%)	78 (33.1%)	76 (39.6%)	
Stroke buckle	690	152 (22.0%)	598	126 (21.1%)	48 (28.2%)	59 (25.0%)	19 (9.9%)	
Non-stroke belt	690	288 (41.7%)	598	254 (42.5%)	58 (34.1%)	99 (41.9%)	97 (50.5%)	
Medical conditions and health behaviors								
Current smoking	690	66 (9.6%)	598	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	4.0 (3.0, 5.0)	3.0 (2.0, 4.0)	4.0 (3.0, 5.0)	4.0 (3.0, 5.0)	<0.001
Physical and mental functioning								
Impaired cognition¶	634	113 (17.8%)	550	105 (19.1%)	24 (15.1%)	46 (21.3%)	35 (20.0%)	0.27
PCS—physical health, median (IQR)	643	41.7 (31.6, 49.9)	559	41.7 (31.9, 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	56.8 (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*
Hospitalization characteristics and transitions to care								
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 (58.9%)	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 were imputed to modeling. HPSA indicates Health Professional Shortage Area; HF, 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 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.

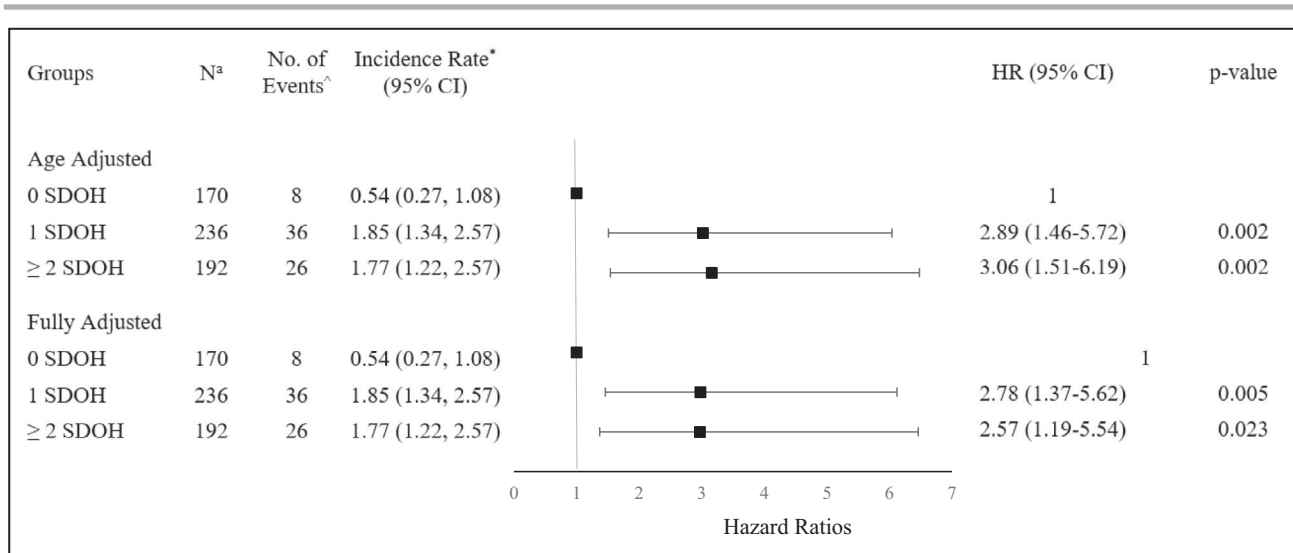


Figure 2. Age- and fully adjusted hazard ratios for SDOH count and 90-day mortality.

[^]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.

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

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.¹³ More recently, studies have shown that health literacy¹⁴ and region of residence (urban versus rural)³⁴ 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.³⁵ At the biologic level, living with SDOH can result in toxic levels of chronic stress that can lead to a sustained allostatic stress response.^{36,37} 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.³⁸ Behavioral mechanisms are likely to play a role here as well. HF requires substantial self-care³⁹ and many older adults hospitalized for HF have significant functional, cognitive, and/or sensory deficits.^{40–43} 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^{44,45} 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,⁴⁶ which could 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,⁴⁷ which could again have downstream effects on health outcomes.³⁴

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.^{3,48} 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.^{49,50} 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 al⁵¹ 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.^{52,53}

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.^{54,55} 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),²⁴ 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

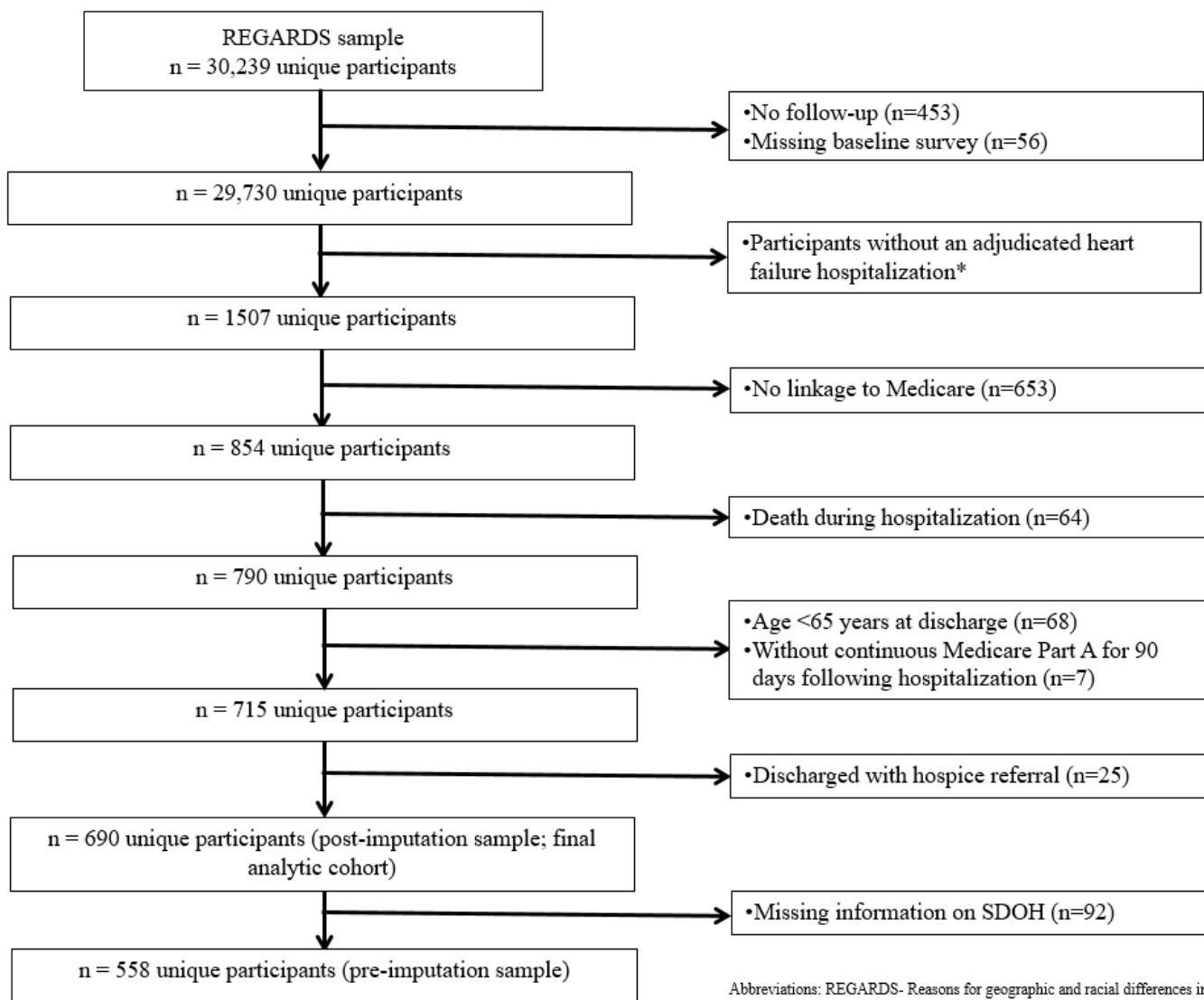
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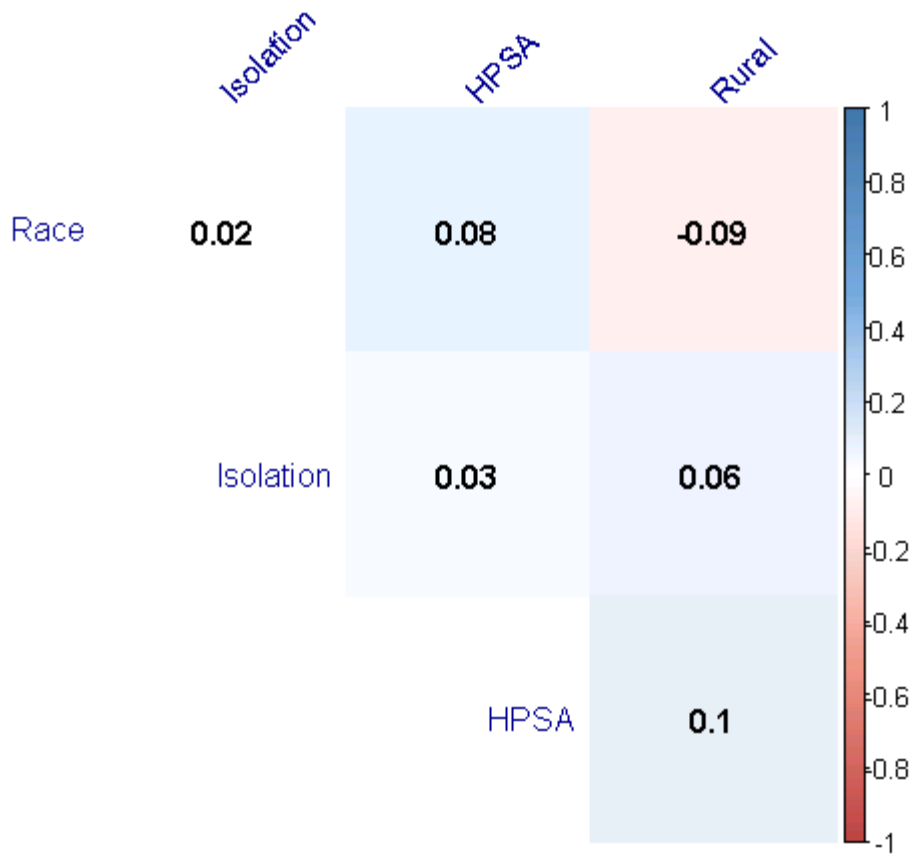
SUPPLEMENTAL MATERIAL

Figure S1. Exclusion Cascade for The Effect of SDOH on 90-Day Mortality after HF Hospitalization in REGARDS.



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.