Original Report: Social Determinants of Health

Should We Implement Geographic or Patient-Reported Social Determinants of Health Measures In Cardiovascular Patients?

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Objectives: To compare patient-reported social determinants of health (SDOH) to the Brokamp Area Deprivation Index (ADI), and evaluate the association of patient-reported SDOH and ADI with mortality in patients with cardiovascular disease (CVD).

Design: Prospective cohort.

Setting: Academic medical center.

Participants: Adults with acute coronary syndrome (ACS) and/or acute exacerbation of heart failure (HF) hospitalized between 2011 and 2015.

Methods: Patient-reported SDOH included: income range, education, health insurance, and household size. ADI was calculated using census tract level variables of poverty, median income, high school completion, lack of health insurance, assisted income, and vacant housing.

Primary outcome: All-cause mortality, up to 5 years follow-up.

Results: The sample was 60% male, 84% White, and 93% insured; mean patient-reported household income was $48,000 (SD $34,000). ADI components were significantly associated with corresponding patient-reported variables. In age, sex, and race adjusted Cox regression models, ADI was associated with mortality for ACS (HR 1.23, 95% CI 1.06, 1.42), but not HF (HR 1.09, 95% CI .99, 1.21). Mortality models for ACS improved with consideration of social determinants data (C-statistics: base demographic model=.612; ADI added=.644; patient-reported SDOH added=.675; both ADI and patient-reported SDOH added=.689). HF mortality models improved only slightly (C-statistics: .600, .602, .617, .620, respectively).

Conclusions: The Brokamp ADI is associated with mortality in hospitalized patients with CVD. In the absence of available patient-reported data, hospitals could implement the Brokamp ADI as an approximation for patient-reported data to enhance risk stratification of patients with CVD. *Ethn Dis.* 2021;31(1):9-22; doi:10.18865/ed.31.1.9

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Background

Social determinants of health (SDOH) predict an estimated 50% of patient outcomes and disproportionately impact the health of disadvantaged populations.[1,2] While the relative influence of one SDOH vs another remains unclear, the overall importance of SDOH on health outcomes and disparities is irrefutable.[1-3] The National Academy of Medicine has identified the importance of systematically screening and addressing SDOH for providing patient-centered and value-based care, improving health outcomes, and improving health equity.[4-7]

Measurement of SDOH is complex and assessment is not routinely implemented into clinical practice due to the challenges of collecting patient-reported data.[8-10] One potential solution is to use publicly available community-level data as a proxy for an individual patient's risks related to socioeconomic status, transportation, access to food, and other factors.[11] One such measure, the Area Deprivation Index (ADI), is based on neighborhood-level variables such as income, housing, and use of public benefits. The Singh ADI is calculated using 17 variables from US census tract data and correlates with outcomes including overall mortality.[11] A newer measure, the Brokamp ADI, uses 6 census tract level variables derived from the 2015 5-year American Community Survey, but has only been evaluated in pediatric populations and has not been tested in adults.[12]

Although using the Brokamp ADI is a potentially pragmatic approach to assessing SDOH in the absence of patient-reported SDOH, research on the association between patient-reported SDOH and the Brokamp ADI is needed. Adults with cardiovascular disease (CVD) are a particularly important group in which SDOH are associated with morbidity and mortality.[13-16] The American Heart Association has called for efforts to address SDOH as an opportunity to reduce morbidity and mortality in patients with CVD.[17]

We assessed SDOH among adults hospitalized with CVD, with two aims. First, we compared the relationship of patient-reported SDOH, specifically income, living below the federal poverty level, education, and health insurance, with equivalent census tract SDOH using the Brokamp ADI. Second, we evaluated the association of these patient-reported SDOH and Brokamp ADI with long-term mortality following hospitalization.

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Methods

Data Sources

This 5-year prospective study enrolled 3000 adult participants treated at a large private academic institution from October 11, 2011 through December 18, 2015. The study was designed to examine how SDOH affect care transitions and outcomes. The data collection was informed by the overall study framework that relates patient characteristics to health outcomes.[18] The institutional review board at Vanderbilt University approved all study procedures. All participants provided written informed consent upon entry into the cohort.

Population

Participants had a physician-confirmed diagnosis of acute coronary syndrome (ACS) and/or acute exacerbation of heart failure (HF) at the index hospitalization. Research staff flagged charts of newly admitted patients for review by a study investigator (either a hospitalist or cardiologist), who applied prespecified criteria that were based on national guideline definitions to confirm a diagnosis of ACS or acute HF by chart review. Study investigators completed an initial training and calibration, as well as periodic calibration throughout study recruitment. Individuals with both ACS and HF were grouped with HF due to similar outcomes, and are henceforth included with HF. Participants were excluded if they had dementia or unstable psychiatric illness, were unable to communicate in English, enrolled in hospice care or were too ill to complete an interview. Two patients who died on the enrollment day were excluded from the analytic cohort.

Independent Variables: Patient-Reported Social Determinants of Health

During the index hospitalization and study enrollment, patients completed a set of validated demographic, cognitive, psychological, social, behavioral, and functional measures.[18] After obtaining informed consent, research assistants administered the 45-minute baseline interview at the bedside. Research assistants received thorough training in effective health communication, including best practices in informed consent, recruitment, and interviewing techniques. Comorbidities were extracted from billing data and summarized as an Elixhauser index,[19] and participants reported how many hospitalizations they had experienced in the 12 months before the index hospitalization. The present analysis focused on patient-reported SDOH that have a corresponding variable in the Brokamp ADI, and thus consisted of household income, educational attainment, and insurance status.

Income data were collected based on methods of the Behavioral Risk Factor Surveillance System, using nine range categories from <$10,000 to >$100,000 (CDC 2010). We recoded <$10,000 to $5,000 and >$100,000 to $112,500. For each of the other categories we used the midpoint of the category to classify the patient.

To parallel the coding used for census tract data, we categorized patient-reported educational attainment as having completed high school (yes/no), and health insurance status as yes/no.

We calculated the federal poverty level (FPL) based on patient-reported household size and the median income value as indicated above, and then categorized each patient as above or below the FPL using the annual poverty guidelines of the US Department of Health and Human Services.[20]

Independent Variable: Brokamp ADI

The Brokamp ADI was derived using a principal component analysis framework and includes six variables based on a patient's home address: 1) poverty (fraction of population with income in the past 12 months below poverty level); 2) median income for the census tract (median household income in the past 12 months in 2015, inflation-adjusted dollars); 3) high school educational attainment (fraction of population aged ≥25 years with at least high school graduation); 4) lack of health insurance (fraction of population with no health insurance coverage); 5) assisted income (fraction of population receiving public assistance income, food stamps, or SNAP in the last 12 months); and 6) vacant housing (fraction of houses that are vacant). The ADI score can range from 0 to 1 with a higher ADI score reflecting higher level of deprivation.[12]

Primary Outcome Variable: All-Cause Mortality

Mortality data were collected for at least 1.25 years, up to 5 years, following the date of index hospitalization, using a combination of data from the Social Security Administration's Death Master File (DMF), documentation in the electronic health record, family report, and obituaries.[21] During this study, the DMF was downloaded monthly into the institutional Enterprise Data Warehouse and linked to patient records by social security number or, when that was not available, through a matching algorithm that uses demographic variables. The DMF is widely used in research and provides accurate matches for death (>90% among American-born individuals) but does omit some events. Supplementing and verifying DMF data with other sources provides a highly accurate ascertainment of vital status.[14,18] Confirmation of vital status was available for all participants using these methods.

Covariates

Important covariates selected *a priori* included age (continuous), sex, race (White, Black, other), and primary diagnosis (heart failure, acute coronary syndrome, or both). Individuals with both ACS and HF were grouped with HF due to similar outcomes, and are henceforth included with HF.

Statistical Analysis

We summarized participant characteristics for the whole study sample, by diagnosis (ACS but not HF, and HF diagnosis) and by quartiles of Brokamp ADI. We used averages and standard deviations for continuous variables and frequencies and percentages for categorical variables.

To evaluate the first aim, we compared components of the Brokamp ADI to the patient-reported variable, when a corresponding variable was available. The four comparisons included education, annual household income, insurance status, and living below FPL. The patient-reported value was considered the reference standard.

We describe the association between Brokamp ADI components and their corresponding binary patient-reported values using side-by-side boxplots and tested the associations with Wilcoxon rank-sum tests. To describe the association between the patient-reported income and census track median income, we used boxplots for census track median income grouped by patient-reported income. We then tested for an association using the likelihood ratio test from a proportional odds logistic regression model. In addition, we calculated a Spearman's correlation between the Elixhauser comorbidity index and ADI, and we used cumulative incidence plots to compare mortality rates across quartiles of ADI.

To evaluate the second aim, we used the calculated Brokamp ADI to determine the association with all-cause mortality from the index date of admission through the end of follow-up, March 2017. Because the prognosis for HF and ACS patients differs, we conducted distinct analyses for these two samples. To examine the relationship between mortality rates after admission to the hospital and patient-report SDOH, ADI, and ADI components, we built six Cox proportional hazards regression models, separately, for the ACS and HF cohorts. Model 1 included basic demographics (age, sex, race); Model 2 included demographics and the Brokamp ADI; Model 3 included demographics and ADI components; Model 4 included demographics and individual-level, patient reported variables; Model 5 included demographics, Brokamp ADI and patient reported variables; and finally Model 6 included demographics, ADI components and patient reported variables. For all models, we report hazard ratios and 95%CIs. We quantify associations with mortality using a hazard ratio per standard deviation change for all continuous variables. To test whether groups of variables improve model fit, we computed likelihood ratio tests (LRT) for demographics variables, ADI components, and patient-reported variables. A Harrell's C-statistic[22] was calculated to evaluate each model's ability to discriminate between those who did and did not die.

Overall, there was a very low rate of missing data (n=134 missing income and n=1 missing household size); however, to avoid loss of information, we used predictive mean matching to construct 10 imputation datasets. Estimates from the imputation-specific analyses were combined with Rubin's Rule.[23]

Across all models, we tested for violations of the proportional hazards assumption using Shoenfeld residuals. For the cases where the proportional hazard assumption was not satisfied, we conducted sensitivity analyses that permitted varying hazard ratios over time. As an additional sensitivity analysis, we added Elixhauser Comorbidity Score and number of hospitalizations in the prior year to all regression models. These variables were chosen as they were uniformly available, applied across the study sample, and were reliable data. All sensitivity analyses are reported in the supplementary materials, available from the corresponding author. Analyses were performed using the statistical software R version 3.6.2 and the package rms.[24-28]

Results

Study Participants

The full Vanderbilt Inpatient Cohort Study (VICS) cohort included 3000 patients, although two patients who died on the day of enrollment were excluded. The final sample size was 2,998 (1878 with ACS and 1120 with HF).

Patient Characteristics

Table 1 shows patient characteristics by diagnosis of ACS vs HF. Study participants were 60% male and 84% White, although the HF group included 20% African Americans. Overall, 93% of patients were insured, and 87% reported at least a high school education. Mean patient-reported household income was $48,000 (± $34,000), with 16% of patients living below the poverty level. Supplemental Tables 1 and 2, available from the corresponding author, demonstrate the patient characteristics by Brokamp ADI quartile for ACS and

Table 1. Participant characteristics stratified by diagnosis and total cohort

Characteristics	Acute coronary syndrome, N=1878	Heart failure, N=1120	Total, N=2998
Covariates			
Age (y), mean ± SD	61 ± 11	60 ± 14	61 ± 12
Male sex, %	62.0 (1164/1878)	55.0 (616/1120)	59.4 (1780/2998)
Race, %			
White	88.6 (1664/1878)	77.3 (866/1120)	84.4 (2530/2998)
Black	9.3 (174/1878)	19.8 (222/1120)	13.2 (396/2998)
Other	2.1 (40/1878)	2.9 (32/1120)	2.4 (72/2998)
Comorbidities (Elixhauser score), mean ± SD	7.4 ± 8.0	15 ± 9.5	10 ± 9.4
Previous-year hospitalizations (N), mean ± SD	1.0 ± 1.8	2.0 ± 2.4	1.4 ± 2.1
Patient-reported variables			
Median income, mean ± SD	$53,000 ± $35,000	$40,000 ± $30,000	$48,000 ± $34,000
Lack of insurance, %	7.0 (132/1878)	6.7 (75/1120)	6.9 (207/2998)
Below FPL, %	13.6 (248/1804)	20.1 (213/1059)	16.1 (461/2863)
Completed high school, %	87.8 (1649/1878)	86.2 (966/1120)	87.2 (2615/2998)
ADI variables (mean ± SD)			
Assisted income (fraction)	.16 ± .10	.18 ± .12	.16 ± .11
Median income	$51,000 ± $23,000	$47,000 ± $20,000	$49,000 ± $22,000
Lack of insurance (fraction)	.13 ± .06	.14 ± .06	.14 ± .06
Below FPL (fraction)	.16 ± .10	.19 ± .12	.17 ± .11
Completed high school (fraction)	.85 ± .09	.84 ± .09	.85 ± .09
Vacant housing (fraction)	.11 ± .07	.12 ± .07	.11 ± .07
Composite ADI	.40 ± .11	.42 ± .12	.41 ± .12
Mortality variables			
Died, %	10.6 (199/1878)	37.1 (415/1120)	20.5 (614/2998)
Time to death (d), mean ± SD	610 ± 450	440 ± 410	500 ± 430

SD, standard deviation; y, year; d, day; FPL, federal poverty level; ADI, Area Deprivation Index.

HF. Elixhauser score was not associated with ADI quartiles (Spearman's correlation .000 and .08 respectively).

Relationship between Brokamp ADI and Patient-Reported SDOH

Overall, patients lived in census tracts in which a median of 16% of the population received assisted income, 14% of the population lacked health insurance, 11% of the housing was vacant, 85% of the population having completed high school, 17% of the population lived below the poverty level, and the median income was $49,000 (Table 1).

Brokamp ADI components were significantly associated with their corresponding patient-reported variables including living below FPL, high school completion, no health insurance, and income range (Figures 1-4).

Association between Brokamp ADI and Mortality

Overall 20.5% of patients died during the follow-up period, al-

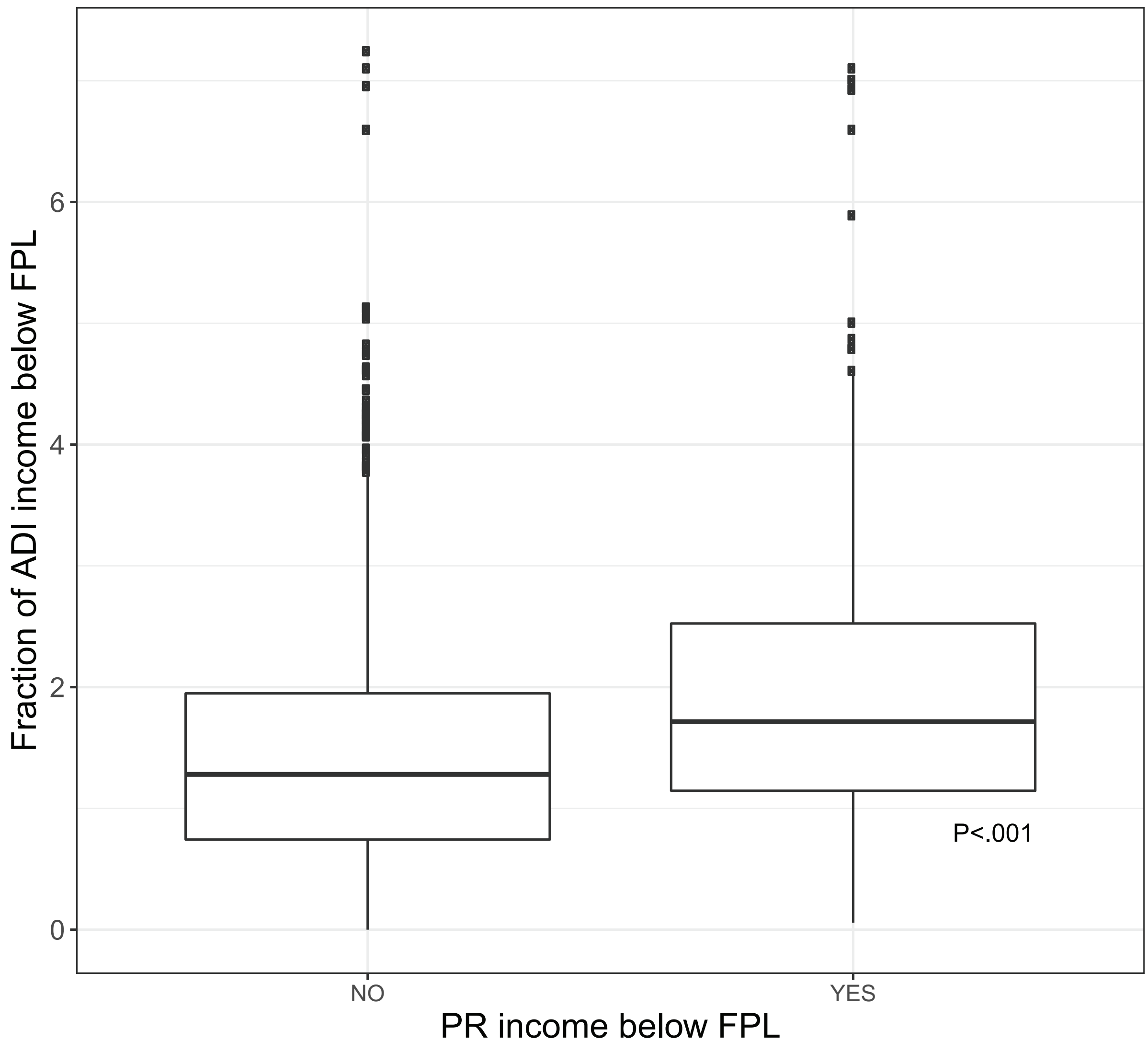

Figure 1. Brokamp ADI components compared with patient-reported variable: Income Below FPL
We characterize associations between Brokamp ADI components and patient-reported variables graphically with boxplots. Wilcoxon rank sum tests were used to evaluate the association between Brokamp ADI components and the corresponding binary patient-reported values (Figures 1-3); income was evaluated with a proportional odds logistics regression of the ordered patient-reported income variable on median income in the census tract (Figure 4). ADI, area deprivation index; FPL, federal poverty level; PR patient-reported.

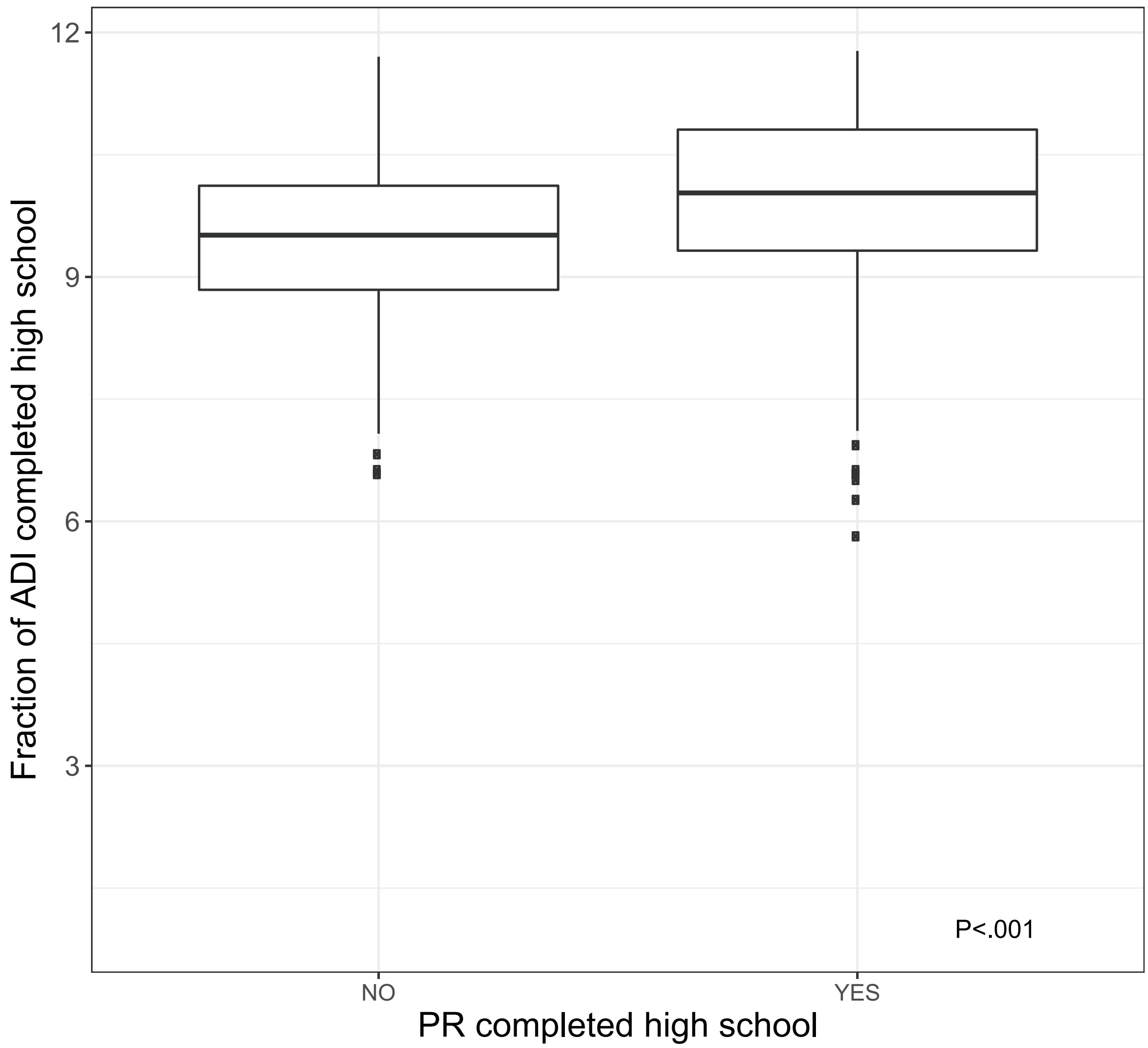

Figure 2. Brokamp ADI components compared with patient-reported variable: Completed high school
We characterize associations between Brokamp ADI components and patient-reported variables graphically with boxplots. Wilcoxon rank sum tests were used to evaluate the association between Brokamp ADI components and the corresponding binary patient-reported values (Figures 1-3); income was evaluated with a proportional odds logistics regression of the ordered patient-reported income variable on median income in the census tract (Figure 4). ADI, area deprivation index; FPL, federal poverty level; PR patient-reported.

though this differed between HF (37.1%) and ACS (10.6%). In the ACS group, cumulative incidence curves stratified by quartiles of composite ADI and demonstrated a graded response between increasing deprivation and mortality (P=.012) (Figures 5, 6).

In ACS, composite ADI was associated with increased mortality (HR 1.23, 95% CI 1.06, 1.42). For the HF group, mortality varied by deprivation level (P=.013), but a dose-response association was not evident. For the HF sample, composite ADI was associated with mortality, however confidence intervals were wide (HR 1.09, 95% CI 0.99, 1.21) (Tables 2 and 3).

Evaluation of Brokamp ADI and Patient-Reported SDOH on Mortality

We constructed six models each for ACS and HF patients to evaluate the mortality association with the components of the Brokamp ADI, the composite Brokamp ADI, and the four available patient-reported SDOH.

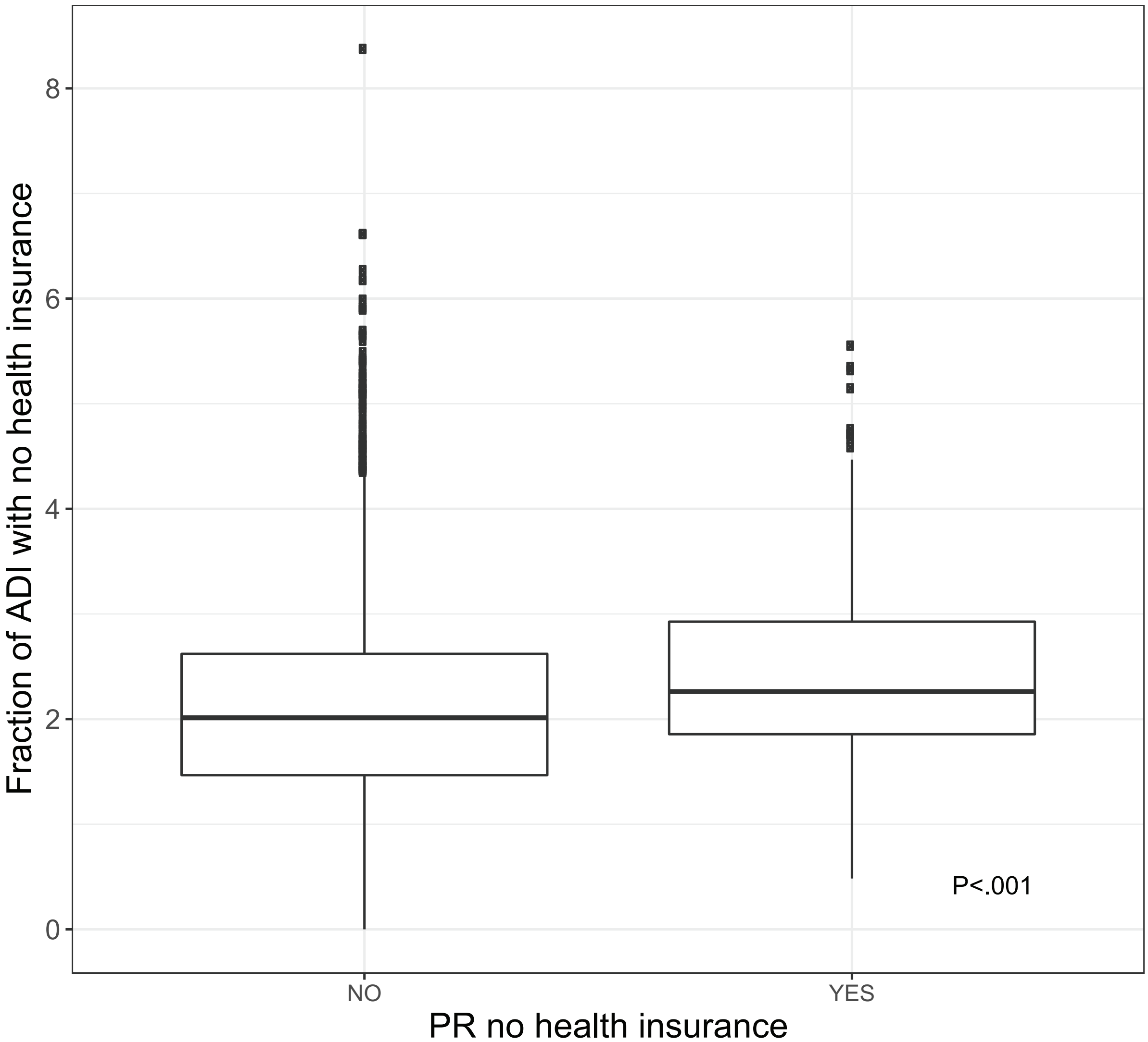

Figure 3. Brokamp ADI components compared with patient-reported variable: No health insurance
We characterize associations between Brokamp ADI components and patient-reported variables graphically with boxplots. Wilcoxon rank sum tests were used to evaluate the association between Brokamp ADI components and the corresponding binary patient-reported values (Figures 1-3); income was evaluated with a proportional odds logistics regression of the ordered patient-reported income variable on median income in the census tract (Figure 4). ADI, area deprivation index; FPL, federal poverty level; PR patient-reported.

In patients with ACS (Table 2), ADI, ADI components, and patient-reported SDOH variables were significantly associated with mortality rates when each was added to a model that only included age, sex, and race (P=.005, .005, and <.001, respectively). In models that included demographics and patient-reported variables, ADI components were still significantly associated with mortality rates (P=.02), but ADI itself was not (P=.257).

In patients with HF (Table 3), the patient-reported variables were associated with mortality (P<.001), but ADI and ADI components were not (P=.079 and .635, respectively). Neither ADI nor its components were significantly associated with mortality rates in models that included demographics and patient reported-variables. The best model fit and C-statistic for mortality included both patient-reported SDOH and Brokamp ADI components (C-statistic .689 for ACS and .620 for HF) (Model 6 in Tables 2 and 3).

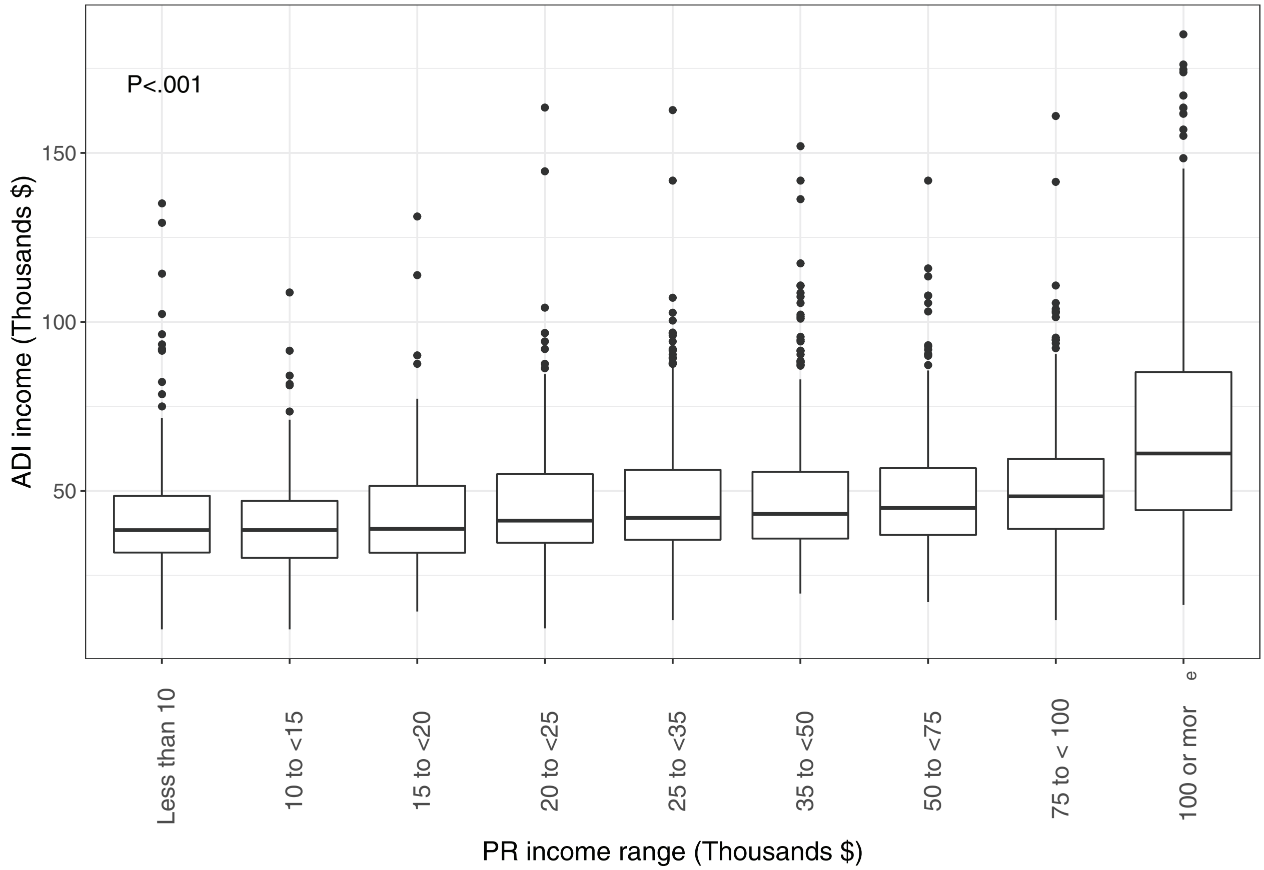

Figure 4. Brokamp ADI components compared with patient-reported variable: Income range
We characterize associations between Brokamp ADI components and patient-reported variables graphically with boxplots. Wilcoxon rank sum tests were used to evaluate the association between Brokamp ADI components and the corresponding binary patient-reported values (Figures 1-3); income was evaluated with a proportional odds logistics regression of the ordered patient-reported income variable on median income in the census tract (Figure 4). ADI, area deprivation index; FPL, federal poverty level; PR patient-reported.

In sensitivity analyses, inclusion of the Elixhauser comorbidity index and number of previous-year hospitalizations in the past year did not change conclusions regarding the relationship between SDOH, ADI and mortality (Supplemental Tables 3, 4 and 5, available from corresponding author).

Discussion

We found two main conclusions. First, census tract variables, as included in the Brokamp ADI, were significantly associated with their corresponding patient-reported SDOH variables. This provides some validation for the Brokamp ADI in adults and suggests that community-level SDOH data are a reasonable reflection of individual SDOH patient-reported data. Second, mortality rates were significantly associated with patient-reported SDOH in both ACS and HF, and with ADI components in ACS. If patient-reported SDOH are unavailable, the Brokamp ADI could be considered for implementation in the electronic health record to improve stratification of patient risk.

Interestingly, we found different effects in the two conditions studied. For patients with ACS, cumulative incidence of mortality increased with each increasing quartile of ADI, suggesting a dose-response relationship between community-level deprivation and mortality. This gradation of mortality with change in ADI was less evident in HF. In fact, SDOH were consistently less associated with mortality among HF participants, which may indicate more prominent effects of complex physiology on HF disease course,

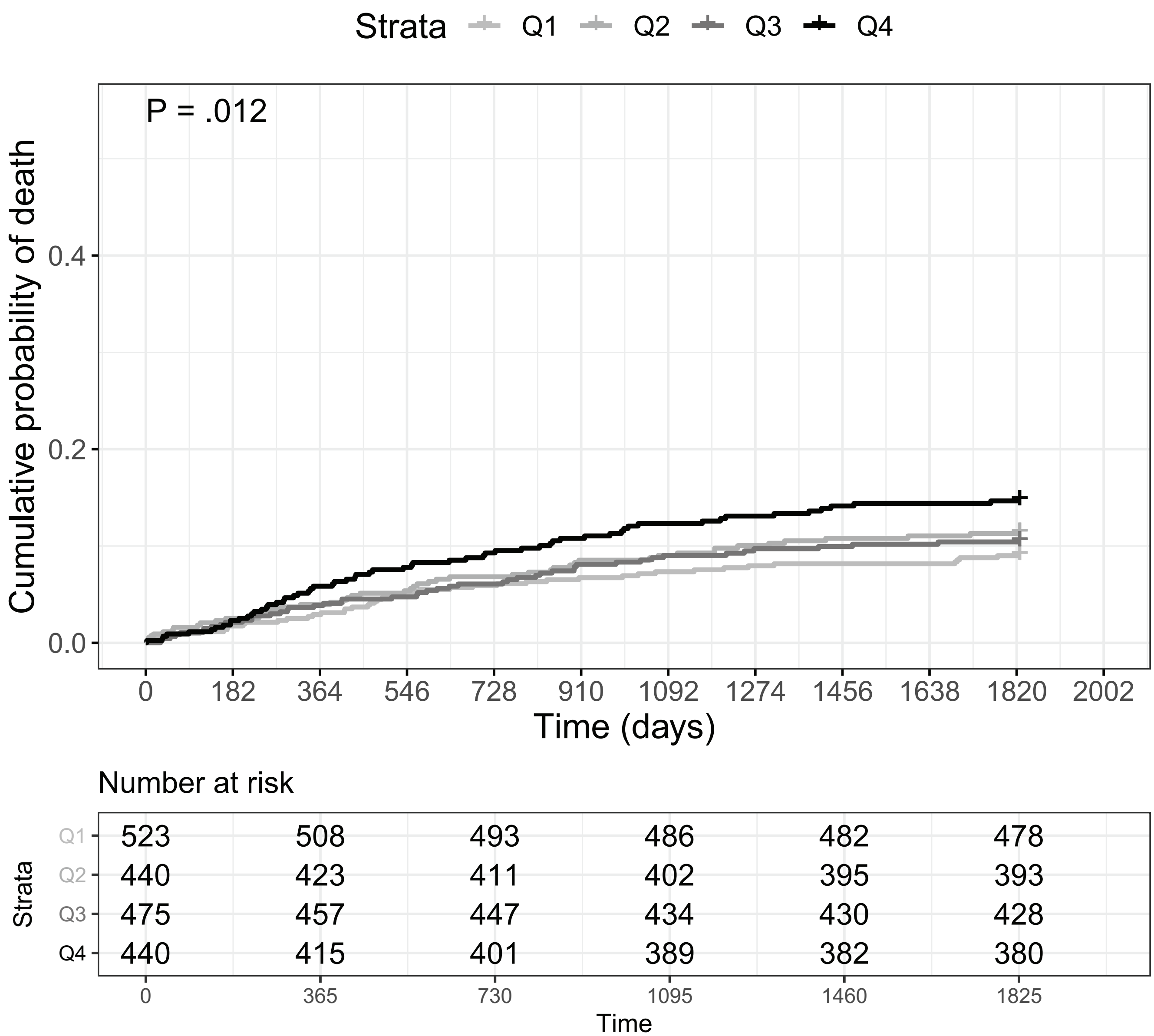

Figure 5. Cumulative incidence of mortality for acute coronary syndrome, by quartile of ADI
ADI quartiles were calculated for full cohort, and cumulative incidence plots were constructed by diagnosis of acute coronary syndrome (Figure 5) and heart failure (Figure 6). ADI, area deprivation index; Q1, quartile 1; Q2, quartile 2; Q3, quartile 3; Q4, quartile 4

though this merits further study.

Notably, the most robust C-statistic for mortality among CVD patients occurred using the combination of both patient-reported SDOH and the Brokamp ADI, reflecting that patient outcomes are likely affected both by their individual SDOH characteristics, as well as the community in which they reside, as shown in previous studies for coronary heart disease and ischemic stroke.[17,29-31] For example, in a multilevel survival analysis investigating the magnitude of geographical variations in ischemic heart disease, Chaix et al found that in non-elderly residents of deprived urban neighborhoods, the neighborhood effect was almost as large as the effect of individual 20-year cumulated income.[30]

Previous SDOH shown to affect

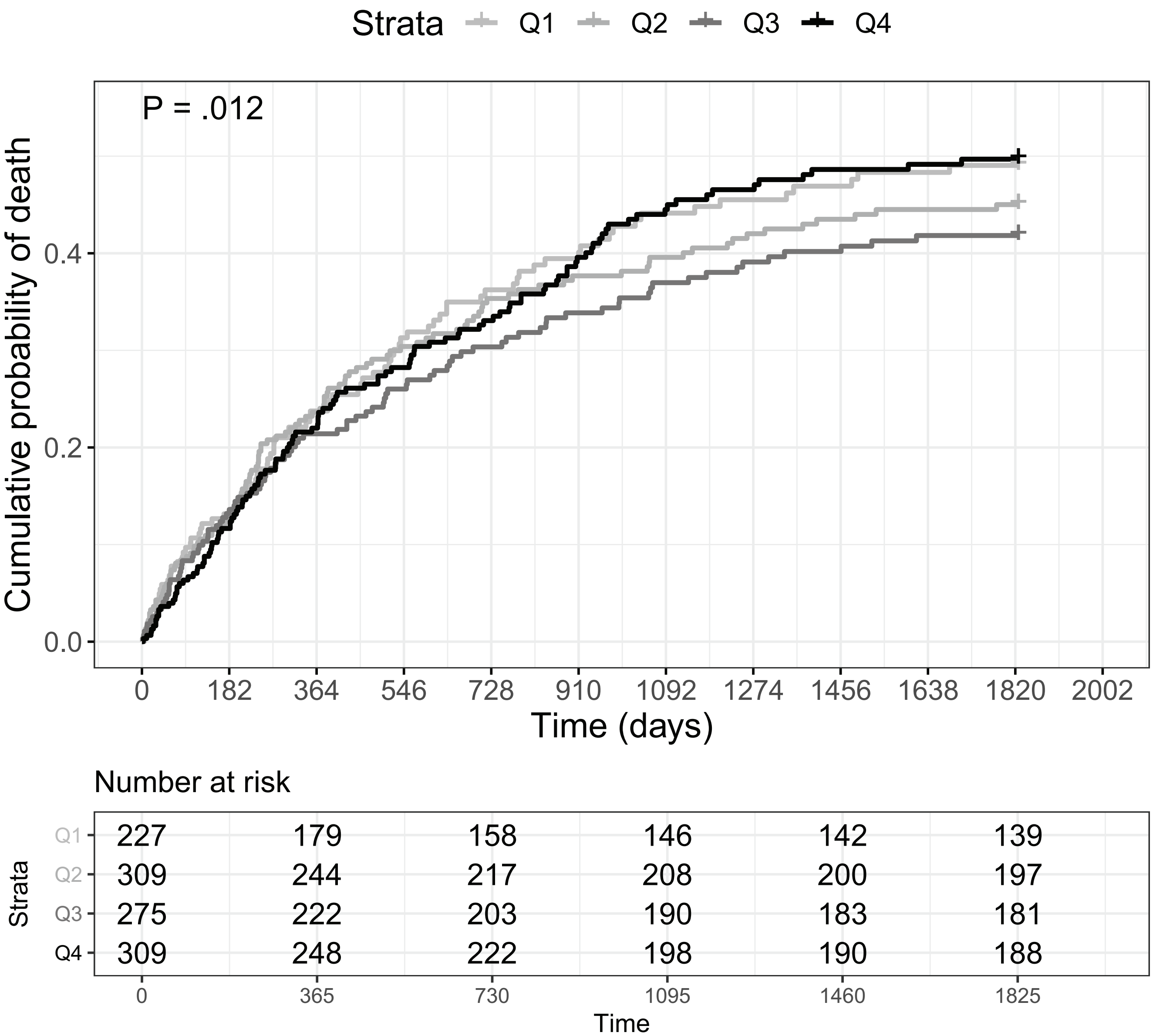

Figure 6. Cumulative incidence of mortality for heart failure, by quartile of ADI
ADI quartiles were calculated for full cohort, and cumulative incidence plots were constructed by diagnosis of acute coronary syndrome (Figure 5) and heart failure (Figure 6). ADI, area deprivation index; Q1, quartile 1; Q2, quartile 2; Q3, quartile 3; Q4, quartile 4

morbidity and mortality in CVD patients include race, socioeconomic status, poverty, education, and health literacy, among others.[13-16] Previous studies using a deprivation index as a predictor for outcomes in CVD have shown mixed utility. Dalton et al showed a neighborhood disadvantage index composed of 11 census-derived variables explained 32% of the variance in cardiovascular events and performed better than traditional risk scores.[32] However, in a machine learning study comparing neighborhood socioeconomic status (an Agency of Healthcare Research and Quality weighted measure of neighborhood deprivation), Bhavsar et al found that this deprivation index did not contribute to risk prediction for hospitalizations for myocardial infarction and

Table 2: Survival analysis for acute coronary syndrome with demographic variables, patient-reported variables, and Brokamp Area Deprivation Index

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Hazard Ratio (95% CI)	Hazard Ratio (95% CI)	Hazard Ratio (95% CI)	Hazard Ratio (95% CI)	Hazard Ratio (95% CI)	Hazard Ratio (95% CI)
Covariates						
Age	1.60[a] (1.36 – 1.87)	1.61[a] (1.37 – 1.89)	1.62[a] (1.38 – 1.91)	1.56[a] (1.33 – 1.83)	1.56[a] (1.33 – 1.84)	1.58[a] (1.34 – 1.86)
Sex (Female: Male)	1.07 (.80 – 1.42)	1.04 (.78 – 1.38)	1.02 (.77 – 1.36)	.84 (.63 – 1.13)	.84 (.63 – 1.13)	.83 (.61 – 1.11)
Race (Black: White)	1.51 (.98 – 2.32)	1.31 (.84 – 2.05)	1.35 (.86 – 2.11)	1.30 (.84 – 2.01)	1.24 (.79 – 1.93)	1.23 (.78 – 1.93)
Race (Other: White)	.53 (.13 – 2.09)	.52 (.13 – 2.06)	.49 (.12 – 1.99)	.44 (.11 – 1.79)	.44 (.11 – 1.79)	1.09 (.94 – 1.27)
Patient-reported variables						
Median income	-	-	-	.64[a] (.53 – .78)	.66[a] (.54 – .80)	.66[a] (.54 – .80)
Lack of insurance	-	-	-	.44[c] (.20 – .96)	.44[c] (.20 – .96)	.44[c] (.20 – .95)
Below FPL	-	-	-	1.27 (.84 – 1.92)	1.26 (.83 – 1.90)	1.35 (.89 – 2.05)
Completed high school	-	-	-	.87 (.58 – 1.28)	.89 (.60 – 1.32)	.87 (.59 – 1.30)
ADI Variables						
Assisted income	-	-	1.04 (.77 – 1.41)	-	-	1.04 (.77 – 1.41)
Median income	-	-	.64[b] (.47 – .88)	-	-	.68[c] (.49 – .94)
Lack of insurance	-	-	1.26[c] (1.05 – 1.51)	-	-	1.26[c] (1.05 – 1.51)
Below FPL	-	-	.85 (.64 – 1.14)	-	-	.86 (.64 – 1.15)
Completed high school	-	-	1.29[c] (1.01 – 1.64)	-	-	1.38[b] (1.09 – 1.76)
Vacant housing	-	-	.42 (.04 – 5.09)	-	-	.25 (.02 – 3.10)
Composite ADI	-	1.23[b] (1.06 – 1.42)	-	-	.43 (.11 – 1.74)	-
C-index	.612	.627	.644	.675	.677	.689
Likelihood ratio tests (LRT) P comparison						
LRT compared with model 1	-	.005	.005	<.001	-	-
LRT compared with model 4					.257	.020

Hazard ratios and 95%CI from Cox proportional hazard models looking at the relationship between time to death, and independent demographic variables, patient-reported variables and Brokamp ADI components.
a. P<.001; b. P<.01; c. P<.05
CI, confidence interval; LRT, likelihood ratio test; ADI, Area Deprivation Index; FPL, federal poverty level
Model 1: demographics; Model 2: demographics + composite ADI; Model 3: demographics + ADI components; Model 4: demographics + patient-reported variables; Model 5: demographics + composite ADI + patient-reported variables; Model 6: demographics + ADI components + patient-reported variables

stroke beyond the predictive ability of 41 predictors already in the EHR (demographics, comorbidities, laboratory tests, medications, and use of health care services).[33] In health policy studies, adjustment for SDOH explains about half of the variation in hospital readmission rates for acute myocardial infarction and heart failure conditions.[34]

The Brokamp ADI specifically has only been evaluated in pediatric populations, where it was associated with health care utilization. Our study contributes to the use and utility of the Brokamp ADI by demonstrating its performance in the adult CVD patients and its association with mortality in a common CVD condition. Interestingly, the ADI in this study was not associated with Elixhauser comorbidity index or number of hospitalizations in the prior year, both variables previously shown to predict 1-year mortality in this same data set[14]; these findings further support its independent association with mortality.

Study Limitations

The limitations of this analysis include a single identification of participant address at the time of index hospitalization. We did not have data on duration of the time spent at that

Table 3: Survival analysis for heart failure with demographic variables, patient-reported variables, and Brokamp Area Deprivation Index

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Hazard Ratio (95% CI)	Hazard Ratio (95% CI)	Hazard Ratio (95% CI)	Hazard Ratio (95% CI)	Hazard Ratio (95% CI)	Hazard Ratio (95% CI)
Covariates						
Age	1.38[a] (1.26 – 1.51)	1.39[a] (1.27 – 1.53)	1.39[a] (1.27 – 1.53)	1.35[a] (1.23 – 1.49)	1.36[a] (1.23 – 1.50)	1.36[a] (1.23 – 1.50)
Sex (Female: Male)	.86 (.70 – 1.04)	.85 (.70 – 1.03)	.84 (.69 – 1.03)	.78[c] (.64 – .95)	.77[c] (.63 – .95)	.70[c] (.58 – .86)
Race (Black: White)	1.13 (.88 – 1.46)	1.07 (.82 – 1.39)	1.08 (.82 – 1.42)	1.11 (.86 – 1.44)	1.08 (.82 – 1.42)	1.08 (.83 – 1.40)
Race (Other: White)	1.10 (.62 – 1.95)	1.09 (.61 – 1.94)	1.11 (.62 – 1.98)	1.00 (.56 – 1.79)	1.00 (.56 – 1.79)	1.01 (.62 – 1.95)
Patient-reported variables						
Median income	-	-		.81[b] (.70 – .92)	.82[b] (.71 – .92)	.80[b] (.70 – .93)
Lack of insurance	-	-		.43[b] (.24 – .77)	.43[b] (.24 – .77)	.42[b] (.23 – .75)
Below FPL	-	-		.93 (.69 – 1.26)	.94 (.69 – 1.27)	.92 (.68 – 1.25)
Completed high school	-	-		1.00 (.75 – 1.33)	1.03 (.77 – 1.38)	1.03 (.78 – 1.38)
ADI variables						
Assisted income	-	-	1.05 (.86 – 1.28)	-	-	1.06 (.86 – 1.29)
Median income	-	-	1.03 (.86 – 1.22)	-	-	1.10 (.93 – 1.31)
Lack of insurance	-	-	1.07 (.94 – 1.20)	-	-	1.07 (.95 – 1.22)
Below FPL	-	-	1.00 (.83 – 1.21)	-	-	1.01 (.84 – 1.15)
Completed high school	-	-	.96 (.81 – 1.14)	-	-	.96 (.82 – 1.14)
Vacant housing	-	-	.58 (.14 – 2.30)	-	-	.62 (.13 – 2.99)
Composite ADI	-	1.09 (.99 – 1.21)	-	-	1.06 (.96 – 1.18)	-
C-index	.600	.603	.602	.617	.619	.620
Likelihood ratio tests (LRT) P comparison						
LRT compared with model 1	-	.079	.635	<.001	-	-
LRT compared with model 4	-	-	-	-	.670	.240

Hazard ratios and 95%CI from Cox proportional hazard models looking at the relationship between time to death, and independent demographic variables, patient-reported variables and Brokamp ADI components.
a. P<.001; b. P<.01; c. P<.05.
CI, confidence interval; LRT, likelihood ratio test; ADI, Area Deprivation Index; FPL, federal poverty level.
Model 1: demographics; Model 2: demographics + composite ADI; Model 3: demographics + ADI components; Model 4: demographics + patient-reported variables; Model 5: demographics + composite ADI + patient-reported variables; Model 6: demographics + ADI components + patient-reported variables.

residence, or for a possible change in address that could have occurred between hospital discharge and death. Additionally, the participants reflected patient characteristics of this referral institution, and further studies are needed to evaluate the ability to determine if associations between mortality and ADI remain in a more diverse patient population. We imputed values for 134 participants (4.5%) of the sample for missing patient-reported income and 1 missing value for household size. It is unknown if these patients are systematically different and were of higher or lower income. Finally, this study evaluates the association of Brokamp ADI with mortality in only one patient cohort with CVD and did not evaluate clinical predictors of mortality. Further research is needed to determine if these associations between ADI and mortality are generalizable to other adult populations.

Conclusion

The Brokamp ADI provides an approach for considering multiple SDOH based on a patient's address. As a clinically practical application, hospitals could implement the Brokamp ADI as an approximation of patient-reported data to enhance risk stratification of patients with cardiovascular disease, if patient-reported data are unavailable. Further research in models that combine self-reported SDOH with the ADI could strengthen clinical application for identifying high risk patients and inform implementation of new strategies to address SDOH. From a population health perspective, increasing local awareness of the association between community-level factors and patient outcomes may stimulate engagement of medical centers in addressing SDOH in the communities they serve.

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Conflict of Interest

No conflicts of interest to report.

Author Contributions

Research concept and design: Kostelanetz, Schildcrout, Kripalani; Acquisition of data: Kostelanetz, Roumie, Conway, Kripalani; Data analysis and interpretation: Kostelanetz, Di Gravio, Schildcrout, Roumie, Kripalani; Manuscript draft: Schildcrout, Conway, Kripalani; Statistical expertise: Kostelanetz, Di Gravio, Schildcrout; Acquisition of funding: Kripalani; Administrative: Kostelanetz, Roumie, Conway; Supervision: Schildcrout, Roumie, Kripalani

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