Excess 30-Day Heart Failure Readmissions and Mortality in Black Patients Increases with Neighborhood Deprivation

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Abstract

**Background:** Longstanding racial disparities in heart failure (HF) outcomes exist in the United States, in part due to social determinants of health. We examined whether neighborhood environment modifies the disparity in 30-d HF readmissions and mortality between Black and White patients in the Southeastern US.

**Methods:** We created a geo-coded retrospective cohort of patients hospitalized for acute HF (AHF) within Emory Healthcare from 2010–2018. Quartiles of the Social Deprivation Index (SDI) characterized neighborhood deprivation at the census tract level. We estimated the relative risk of 30-d readmission and 30-d mortality following an index hospitalization for AHF. “Excess” readmissions and mortality were estimated as the absolute risk difference between Black and White patients within each SDI quartile, adjusted for geographical clustering, demographic, clinical, and hospital characteristics.

**Results:** The cohort included 30,630 patients, mean age 66 years, 48% female, 53% Black. Compared with White patients, Black patients were more likely to reside in deprived census tracts, and have higher comorbidity scores. From 2010 to 2018, 29.4% of Black and 23.0% of White patients experienced either a 30-d HF readmission or 30-d death (p<0.001). Excess in composite 30-d HF readmissions and mortality for Black patients ranged from 3.9% (95%CI: 1.5%−6.3%; P=0.0002) to 6.8% (95%CI: 4.1% −9.5%; P<0.0001) across SDI quartiles. Accounting for traditional risk factors did not eliminate the Black excess in combined 30-d HF readmissions and/or mortality in any of the neighborhood quartiles.

**Conclusions:** Excess 30-d HF readmissions and mortality are present among Black patients in every neighborhood strata, and increase with progressive neighborhood socioeconomic deprivation.

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Keywords

heart failure; hospitalization; race/ethnicity; neighborhood; social deprivation index

Heart failure (HF) affects approximately 6.5 million Americans, and is the primary diagnosis in almost 1 million hospitalizations each year at a cost of >$30 billion annually.1,2 Despite recent trends demonstrating improvements in clinical outcomes, 1-year mortality after HF hospitalization (HFH) remains high, and ~25% of patients are readmitted within 30 days of an index HFH.1,3 Since the Center for Medicare and Medicaid Services implemented the Hospital Readmissions Reduction Program (HRRP) in 2014, substantial financial penalties are imposed on health care systems that fail to meet expected rates of 30-day readmissions after a hospitalization for 5 common hospital conditions, including HF. Thus, preventing readmissions for HF patients has become a high priority for many hospital systems, including those across the Southeastern US where rates of HF hospitalization are amongst the highest in the country.4–6

Existing models that predict risk for HF readmission may underperform because many focus narrowly on readily available administrative data, patient-level clinical factors, or hospital characteristics. However, they ignore neighborhood-level factors that are instrumental drivers of index hospitalization and readmissions. There is increasing awareness that social determinants of health (SDOH), including neighborhood and environment, both precipitate and perpetuate cardiovascular disease (CVD).7,8 Prior analyses suggest that much of the variation in healthcare expenditures and CVD mortality are explained by social and economic factors to a greater extent than by health behaviors or characteristics of healthcare systems.9–11 Viewing individual clinical risk factors in isolation may obscure “upstream” drivers of CVD risk and prevent identification of potential approaches to modify patient-level behaviors proximally linked to disease development and management. For example, lack of access to particular resources (i.e. medical care, grocery stores, etc), increased psychosocial stressors due to lack of safety and social cohesion, and attributes of the built environment (i.e. availability of transportation, greenspace, housing stability) collectively impact lifestyle behaviors including diet, physical activity and smoking.12–14

Neighborhood socioeconomic status (nSES) predicts incident HF as well as the burden of hospitalizations in patients with prevalent HF.15,16 Although it is currently unclear whether incorporating data on factors relevant to patients’ post-discharge residential environment improves HF-readmission risk prediction models, these data may be particularly important when examining health disparities and mechanisms to help patients improve the complex self-management associated with HF.7,10,17 Black Americans are more likely to live in low SES neighborhoods, and have a higher risk for HF hospitalizations and 30-d readmissions compared to other race-ethnic groups.16,18 Moreover, risk associations based on self-reported race-ethnicity differ across regions of the country, suggesting effect modification by local factors.19,20 There are currently few analyses that examine the intersection of nSES and race-ethnicity in predicting HF clinical outcomes. Local environments in the Southeastern US represent an ideal setting to examine the complex associations of race-ethnicity, neighborhood deprivation, and HF risk, as the Southeastern US has a
disproportionately high number of hospital admissions for HF compared to other regions of the country. Moreover, the legacy of slavery, racial discrimination and segregation have led to severe economic inequalities that are associated with particularly poor modern-day CVD outcomes for Black persons in the Southeastern US. In this manuscript, we sought to examine the racial disparity in 30d-readmissions and mortality in a retrospective cohort of patients hospitalized for acute HF (AHF) in a large healthcare system in the Southeast. Furthermore, we combined both clinical and post-discharge environmental characteristics to test the hypothesis that nSES modifies the disparity in 30-d HF readmissions and mortality between Black and White patients in this setting.

Methods

Data source

We utilized the Emory Healthcare Clinical Data Warehouse (EHC-CDW), a data repository that integrates standardized patient-level data from the electronic medical records (EMR) across the Emory Healthcare system, the largest and most comprehensive hospital system in Atlanta, Georgia. For this analysis, we examined data from Emory University Hospital (EUH) and Emory University Hospital Midtown (EUHM) since they are staffed primarily by Emory clinicians and housestaff, and are each equipped with their own large general medicine, general cardiology, and advanced HF services. Available data within the EHC-CDW includes both inpatient and outpatient visit data, provider information, diagnoses and procedures, clinical laboratory results, clinician documentation, pharmacy, and emergency department utilization. Because of the sensitive nature of the data collected for this study, requests to access a subset of the data from qualified researchers trained in human subject confidentiality protocols may be sent to the corresponding author. This study was approved by the Emory Institutional Review Board.

Study population

We conducted a retrospective cohort study of all patients aged ≥18 years admitted within the Emory Healthcare System with a primary or secondary discharge diagnosis of AHF (based on International Classification of Diseases-Ninth or Tenth Revision, Clinical Modification codes 428.x and I50.x) for both the index hospitalization as well as any rehospitalizations from January 1, 2010 to December 31, 2018. Cases included patients with both prevalent and incident HF. Self-reported race-ethnicity and residential address were extracted from the EMR information available in CDW. We included all Black and White patients, and excluded patients with other racial identifiers owing to limited numbers (N=2,547).

Clinical covariates

We considered a prespecified list of clinical and hospital characteristics extracted from the EMR at the time of admission during the index AHF hospital encounter, including: sociodemographic characteristics (age, sex, insurance status), HF type (systolic, diastolic, other), medical comorbidities (hypertension, diabetes mellitus, chronic kidney disease, coronary artery disease, atrial fibrillation, chronic obstructive pulmonary disease, peripheral vascular disease, and cerebrovascular accident/transient ischemic attack), vital signs (systolic blood pressure, heart rate, and respiratory rate), laboratory values (serum sodium,
creatinine, estimated glomerular filtration rate [eGFR], blood urea nitrogen, hemoglobin, B-type natriuretic peptide [BNP] and troponin [TNI]), year of index hospitalization, discharging specialty (cardiovascular, hospitalist / internal medicine, other), hospital location (EUH vs EUHM), and medications. The Charlson comorbidity index was derived as a summary measure of the medical comorbid conditions. For patients with missing eGFR values (N=13,377), we derived eGFR from serum creatinine using the Modification of Diet in Renal Disease equation.

Clinical outcomes

The primary endpoints of interest were HF readmissions and all-cause death at 30-days, similar to metrics publicly captured and reported by the Centers for Medicare and Medicaid Services (CMS). A composite endpoint of death and readmission was derived as experience of either 30-d HF readmission or 30-d death. Individuals who experienced neither 30-d HF readmission or 30-d death were the reference category for this outcome. Dates of rehospitalization or death at any time during the follow-up period were captured in the EMR.

Geocoding and assigning the nSES

The Social Deprivation Index (SDI) summarizes 7 socio-demographic measures taken from the US Census American Community Survey. The SDI was developed through a factor analysis of the percentage of the population that lives in poverty, percentage with less than 12 years of education, percentage of single parent households, percentage living in rented housing units, percentage living in overcrowded housing units, percentage of households without a car, and percentage of non-employed adults under 65 years of age. For this analysis, we used the SDI at the census tract level developed from the 2015 American Community Survey. To assign each patient an SDI value, patient addresses were geocoded to street level accuracy using the US Census Bureau’s geocoder. Census tracts were chosen as proxies for neighborhoods because they are relatively fixed county subdivisions that are generally have homogenous population characteristics, socioeconomic status and living conditions. Scores range from 1 to 100, with a higher score indicating greater census tract deprivation.

Statistical analysis

Patient characteristics, including demographics, medical comorbidities, and laboratory values are presented according to racial group at the time of the index hospitalization for AHF. Data are presented as mean (standard deviation) for normally distributed continuous variables, median (interquartile range) for non-normally distributed continuous variables, or N (%) for categorical variables as appropriate.

We estimated the risk of experiencing 30-d HF readmission, 30-d mortality, or the composite endpoint over the 8 year study period in the full sample, and the sample stratified by race. We next estimated the unadjusted and adjusted risk ratio of each outcome comparing Black with White patients using log binomial regression (or Poisson model in cases of non-convergence) with generalized estimating equations to account for patient clustering within census tracts and to account for the potential for multiple readmissions within the same
patient. All models further accounted for potential clustering of patients within hospital site using a fixed effect. Model 1 adjusted for year of index hospitalization, hospital location, and sociodemographic characteristics, Model 2 additionally adjusted for medical comorbidities, vital signs, and laboratory values, and Model 3 additionally adjusted for discharging specialty. BNP and TNI were not included in the multivariable models due to a large amount of missingness. Given the younger age of onset of heart failure with reduced ejection fraction (HFrEF) in Black patients and recent analyses suggesting that racial disparities worsen after adjustment for age, we performed a pre-specified subgroup analysis by age (<65 or ≥65 years) and by HF type with appropriate tests for statistical interaction.

To examine the potential for neighborhood deprivation as an effect modifier of the racial disparity in HF outcomes, we estimated the excess risk of 30-d readmission and mortality in Black versus White patients by quartiles of the SDI scores among our patient cohort (least deprived quartile [1–41], quartile 2 [42–65], quartile 3 [66–85], and most deprived quartile [86–100]). SDI was analyzed as a categorical variable defined as quartiles to allow for non-linear modification between neighborhood deprivation and the racial disparity in outcomes while maintaining interpretability of the findings. Excess risk was estimated as the absolute risk difference in 30-d HF readmission and 30-d mortality between Black and White patients using linear probability models with generalized estimating equations to account for patient clustering within census tracts. Parallel to the models of relative risk, absolute risk difference models were progressively adjusted for the same covariates in Models 1 to 3 described above. To formally evaluate effect modification, we tested the statistical interaction between neighborhood deprivation and race through a cross-product interaction term between SDI quartile and race in the base and fully adjusted model for each outcome separately.

All statistical analyses were conducted using SAS statistical software version 9.4 (Cary, NC). All p values are two-tailed with a significance threshold of <0.05.

Results

The initial cohort included 41,614 patients discharged with a primary or secondary diagnosis of AHF between January 1, 2010 and December 31, 2018 from 2 hospitals within the Emory Healthcare system. After excluding 2,547 patients for race-ethnicity besides Black or White, 8,406 patients who lacked information on residential address or who resided in census tracts missing data on the SDI, and 2,749 patients who lacked information on important clinical covariates, the final analytic cohort included 30,630 patients and 64,323 hospital encounters for AHF over a median follow-up period of 3.5 years. Patient characteristics at the index hospitalization were largely similar between those analyzed and those excluded due to missing data (see Supplemental Table 1). The mean age of patients in the analytic cohort was 66 years, 48% were women, and 53% were Black (Table 1). HFrEF was the most common HF diagnosis, and hypertension was the most common medical comorbidity. Most clinical covariates differed significantly by race. Of note, Black patients were younger, more likely to have Medicaid insurance and had a higher Charlson comorbidity index. Black
patients were more likely to be cared for on internal medicine rather than cardiology specialty services, and were more likely to be hospitalized at EUHM.

During a median follow-up of 3.5 (IQR 1.2 – 6.6) years, patients experienced an average of 2.1 admissions for AHF (Table 2). The absolute risk of 30-d HF readmission and 30-d mortality following the index HF hospitalization was 17.2% and 12.6%, respectively. Black patients experienced a higher total number of admissions for AHF and 30-d readmissions, and experienced a marginally higher absolute risk of death. The higher risk of 30-d readmissions, 30-d mortality, and the composite endpoint in Black patients was consistently observed in most age and HF type strata except mortality among adults aged <65 years (Figure 1).

Table 3 shows unadjusted and adjusted relative risks of 30-d HF readmission, 30-d mortality, and the composite endpoint in Black compared to White patients. In the fully adjusted model accounting for sociodemographic characteristics, medical comorbidities, and hospital factors, the relative risk of 30-d readmission for HF, 30-d all-cause mortality, and the composite endpoint remained higher for Black compared to White patients. The findings were similar when stratified according to age or HF type (Supplemental Table 2).

When examining the distribution of White and Black patients across quartiles of the SDI, a higher proportion of White patients resided in the least deprived neighborhoods, while a higher proportion of Black patients resided in the most deprived neighborhoods (Figure 2). Patients living in the most deprived SDI quartile were more likely to have a history of hypertension, diabetes, and CKD, and had higher measured blood pressure (Supplemental Table 3).

To investigate whether there is evidence of effect modification of neighborhood deprivation on racial disparities in HF outcomes, we estimated the excess risk of 30-d readmission and 30-d mortality associated with Black race in each quartile of the SDI separately. After accounting for sociodemographic characteristics, hospital location, and year of the index hospitalization, the excess in 30-d HF readmissions associated with Black race was observed in each quartile of the SDI, and ranged from 5.0% in the least deprived SDI quartile to 8.3% in quartile 3 (Figure 3A). Further adjustment for medical comorbidities and discharging specialty only modestly attenuated the excess in 30-d HF readmissions associated with Black race in the SDI quartiles. In similar analyses of 30-d mortality by quartiles of the SDI, the fully adjusted excess in 30-d mortality associated with Black race ranged from 2.5% to 3.2%, but was only observed in the most deprived SDI quartiles (Figure 3B). The composite endpoint of 30-d HF readmission and mortality again demonstrated excess risk associated with Black race in each quartile of the SDI, with higher risk in the most deprived SDI quartiles (Figure 3C).

**Discussion**

In this analysis of 30,630 patients hospitalized for AHF within a single healthcare system in the Southeastern US from 2010 to 2018, we observed a higher risk of adverse 30-d clinical outcomes for Black patients with HF. Our findings confirm those seen in prior analyses,
including a higher burden of traditional CV risk factors, decreased likelihood of primary inpatient AHF care delivered by cardiovascular specialists\textsuperscript{32}, and worse clinical outcomes in Black patients.\textsuperscript{18, 19} Our findings are novel in that we examined the risk for clinical outcomes in conjunction with patient-level neighborhood data. Even after accounting for traditional variables used to risk-adjust for CV outcome measures (i.e. demographics, medical comorbidities, and hospital characteristics), Black patients had a higher risk of adverse clinical outcomes within each quartile of the SDI, with increased risk in the most deprived neighborhoods. These findings re-emphasize the critical fact that many determinants of health outcomes occur outside of the context of the healthcare system, and that efforts to eliminate health inequities must first examine the structural and systemic inequities that place certain individuals at higher risk for poor health outcomes to begin with.

Fundamental social causes of disease theory states that “inequities in disease rates between socially stratified groups reflect the groups’ differential access to the technology, knowledge, and resources necessary to prevent or treat disease”.\textsuperscript{33} Consequently, inequalities in health and mortality will persist as long as resource inequalities persist as well.\textsuperscript{33} Examining the burden of CVD in the Southern US offers a particularly unique view on the complex association between race, resource inequalities, and health outcomes. Rates of CVD morbidity and mortality remain higher in the Southern US, in part due to a higher prevalence of traditional CV risk factors.\textsuperscript{4, 6, 34} However, the legacies of slavery and racial segregation that are deeply embedded in the fabric of Southern life and policy have also had a persistent negative impact on health outcomes. Recent analyses demonstrate that US counties with the highest concentration of slaves in 1860 (almost all of which were in the South) have experienced slower rates of decline in CVD mortality compared to counties with a lower slave concentration in 1860.\textsuperscript{21, 22} With respect to CVD mortality, nearly half of the slower rate of decline can be explained by modern-day educational and economic racial inequalities.\textsuperscript{22} More recent government-sanctioned programs, such as redlining that was practiced throughout the US, have resulted in persistent patterns of economic inequality and racial segregation, leading to drastic inequities in how resources are distributed at the neighborhood level.\textsuperscript{35} Black individuals remain more likely to live in high-poverty neighborhoods characterized by poor housing, diminished school quality, limited access to employment opportunities and healthcare, and greater exposure to crime, noise, and pollution.\textsuperscript{36} Thus, it is important to investigate and contextualize the deeply rooted social structures and legacies that continue to drive modern-day disparate health outcomes.

Against this historical backdrop, it is not surprising that multiple prior studies have identified residential neighborhood as a risk factor for incident HF as well as HF readmissions.\textsuperscript{15, 16, 37} An analysis of 1557 participants in the Telemonitoring to Improve Heart Failure Outcomes trial demonstrated that individuals living in low-SES neighborhoods were more likely to be readmitted within 6 months than those in high-SES neighborhoods, even after adjusting for individual SES and clinical comorbidities.\textsuperscript{38} Similarly, a prior analysis of 457 patients with HF in the metropolitan Atlanta area demonstrated the overall frequency of recurrent all-cause and HF-specific hospitalizations was higher in subjects who lived in a food desert.\textsuperscript{16} A prior analysis of hospitalized HF patients from the Get With the
Guidelines-Heart Failure registry confirmed a higher risk for 30-day readmissions among Black and Hispanic patients that was attenuated after adjustment for county-level SES.\(^\text{17}\)

Although prior analyses have demonstrated excess risk of 30-d readmissions in Black patients, we also demonstrate excess risk of 30-d mortality for Black patients in our cohort. The excess risk of mortality observed in the most deprived neighborhoods persisted even after adjusting for traditional risk factors and neighborhood environment, and may explain why excess readmissions were lower in quartile 4 compared to quartile 3. The observations in this analysis highlight the importance of regional studies that are able to identify disparate patterns of clinical outcomes that may be masked when epidemiologic data are only examined at the national level. The excess in 30-d mortality in our cohort may in part reflect Georgia’s history of racial segregation that has adversely impacted health for Black patients.\(^\text{22}\) Moreover, Georgia failed to expand Medicaid under the Affordable Care Act leading to reduced healthcare access for many patients. Finally, Emory is one of only 2 healthcare centers in the entire state that is able to provide comprehensive advanced HF services, resulting in a higher than average patient acuity. Prior studies demonstrate Black patients with HF are referred for advanced therapies later in their disease course\(^\text{39}\), and this late presentation may also contribute to the increased mortality in our population.

One unique strength of our analysis is the large sample size that includes patients with multiple insurance types and utilizes patient-level address data. Many existing analyses focus primarily on patients with Medicare insurance in an effort to validate the risk-standardization methods used by CMS. However, patients with frequent hospitalizations represent a high-risk cohort irrespective of insurance status, and younger patients with Medicaid insurance may in fact be a more vulnerable group due to fewer resources.\(^\text{40}\) Administrative datasets that characterize patient geolocation by zip code or hospital location may fail to capture the heterogeneity of the lived environment within these artificially designated boundaries. Moreover, while zip codes are drawn by the US postal service to establish efficient carrier routes, census-derived boundaries such as census tracts and block groups are created to be socioeconomically homogeneous, and reflect community resources and neighborhood environments in which patients live with greater precision.\(^\text{41}\)

Multiple mechanisms may account for the influence of residential neighborhood on HF outcomes. Compared to those in high-SES neighborhoods, persons living in low-SES neighborhoods have worse diet quality and more sedentary lifestyle, in part due to reduced access to grocery stores and outlets for physical activity, contributing to a greater prevalence of CV risk factors that associate with HF risk and severity.\(^\text{8, 42, 43}\) Lack of access to fresh, low sodium foods may have particularly deleterious consequences for patients with HF, who are almost universally counselled to eat low sodium diets, and require fairly meticulous self-care and frequent medication changes to maintain euvolemia.\(^\text{7, 44}\) However, in the current investigation, the black excess risk in HF readmissions and mortality persisted in even the least deprived neighborhoods, even after adjusting for diabetes and hypertension. Beyond traditional CV risk factors and lifestyle behaviors, novel mechanisms may contribute to the risk for HF in patients who live in low SES neighborhoods. Epigenetic biomarkers, including DNA methylation, histone modifications, and expression of non-coding RNAs, are important molecular mechanisms underlying disease progression in HF.\(^\text{45}\) Multiple
epidemiologic studies have utilized the same epigenetic biomarkers to document the cumulative effects of lifetime exposures related to residential environment, either through chemical exposures or stress-induced processes including inflammation.\textsuperscript{46–48} Future research should examine whether epigenetic changes mediated through neighborhood environments may be one mechanism that contributes to the more severe HF phenotype observed in Black Americans.

There are limitations to this analysis that are worth noting. We lacked information on factors that characterize SES at the individual level, including individual income and level of education. Social determinants of health, however, are determined by numerous, highly interrelated factors including individual SES, race-ethnicity, social support and networks, culture, language, access to medical care, and residential environments.\textsuperscript{8} Similarly, we lacked data on patient-level behaviors that could also impact risk for readmission and vary by neighborhood. Although we were unable to incorporate information on ejection fraction, leaving many patients under the classification “HF other”, the risk estimates for this group were very similar to those seen for patients appropriately classified as systolic and diastolic HF, confirming the association of neighborhood SES and race-ethnicity with HF outcomes is independent of HF classification. Similar to prior analyses\textsuperscript{49, 50}, we did not include prescription of guideline-directed medical therapy in the regression models, since the cohort included patients with multiple HF types. Other clinical variables that impact mortality, including HF severity defined by New York Heart Association class, prior implantable cardioverter-defibrillator, ischemic HF etiology, etc. were not included in this analysis, because they were not consistently coded for across hospital encounters resulting in substantial data missingness. Finally, readmissions that occurred in other local healthcare systems or out-of-hospital deaths that we did not capture could have biased our estimates.

In conclusion, our study demonstrates excess risk of 30-d HF readmission and mortality in Black patients compared with White patients across all neighborhoods, with increasing excess risk with greater social deprivation. Our findings confirm and support those of prior analyses that suggest factors beyond the healthcare system drive excess readmissions, particularly for patients who are socially vulnerable. Without appropriate risk adjustment for social determinants of health, the financial penalties imposed by the HRRP are fundamentally problematic and may be excessively punitive for safety net hospitals that care for patients who are the most socioeconomically disadvantaged.\textsuperscript{40} Our analysis reiterates the critical need for healthcare policies to account for the differential health risks associated with neighborhood deprivation in general, and the uniquely worse health risks for Black patients in who live in deprived neighborhoods.

\textbf{Supplementary Material}

Refer to Web version on PubMed Central for supplementary material.

\textbf{Sources of Funding:}

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Nonstandard Abbreviations and Acronyms

- **AHF**: acute heart failure
- **CDW**: clinical data warehouse
- **EUH**: Emory University Hospital
- **EUHM**: Emory University Hospital Midtown
- **EMR**: electronic medical record
- **HFH**: heart failure hospitalization
- **HRRP**: Hospital Readmissions Reduction Program
- **SDI**: social deprivation index
- **SDOH**: Social determinants of health

References


33. Firebaugh G and Acciai F. For Black patients in America, the gap in neighborhood poverty has declined faster than segregation. Proc Natl Acad Sci U S A. 2016;113:13372–13377. [PubMed: 27821759]


Clinical Perspective

What Is New?

- The reasons that Black patients with heart failure have a higher risk for 30-d readmissions are multifactorial, including a higher burden of traditional cardiovascular risk factors, social determinants of health, bias in the health care setting, and other factors.

- We combined clinical and neighborhood environment characteristics to determine whether neighborhood socioeconomic status modifies racial disparities in 30d- readmission and mortality in a cohort of patients in the Southeastern United States.

What Are the Clinical Implications?

- Even after taking clinical factors and neighborhood environment into account, we demonstrated that Black patients have a higher risk of adverse clinical outcomes at every quartile of the social deprivation index. Our findings highlight increased risk of adverse clinical outcomes in Black patients with increasing social deprivation, but also increased risk for Black patients irrespective of socioeconomic status.

- Healthcare policies need to account for the substantial residual health risks associated with neighborhood deprivation in general, and the uniquely worse health risks for Black patients in who live in deprived neighborhoods.
Figure 1A. 30-d HF Readmissions in White and Black Patients by Age

Risk of 30-d Readmission

Age <65 y

13.2%

Age ≥ 65 y

13.6%

21.2%***

19.9%***

White Patients

Black Patients
Figure 1B. 30-d HF Readmissions in White and Black Patients by HF type

- HFrEF: 15.3% (White Patients) vs. 23.4%*** (Black Patients)
- HFrEF: 13.7% (White Patients) vs. 21.1%*** (Black Patients)
- Other HF: 10.5% (White Patients) vs. 15.0%*** (Black Patients)
Figure 1C. 30-d Mortality in White and Black Patients by Age

Risk of 30-d Mortality

- Age < 65 y: 10.8% (White Patients), 10.8% (Black Patients)
- Age ≥ 65 y: 12.9% (White Patients), 15.2%*** (Black Patients)
Figure 1D. 30-d Mortality in White and Black Patients by HF type

<table>
<thead>
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<th>HF Type</th>
<th>Risk of 30-d Mortality</th>
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<tr>
<td>HFpEF</td>
<td>Red: 13.0%</td>
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<tr>
<td>Other HF</td>
<td>Blue: 9.5% Red: 11.0%*</td>
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<tr>
<td></td>
<td>Blue: 13.9%</td>
</tr>
<tr>
<td></td>
<td>Red: 14.6%</td>
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</table>

Legend:
- Blue: White Patients
- Red: Black Patients
Figure 1E. 30-d Composite Readmission/Mortality in White and Black Patients by Age

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Risk of 30-d Readmission/Mortality</th>
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<td>21.6%</td>
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<tr>
<td>Age ≥ 65 y</td>
<td>28.2%***</td>
</tr>
<tr>
<td></td>
<td>23.7%</td>
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<tr>
<td></td>
<td>30.7%***</td>
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</table>

Legend: Blue = White Patients, Red = Black Patients
Figure 1F. 30-d Composite Readmission/Mortality in White and Black Patients by HF type

Figure 1. Absolute risk of 30-d HF readmissions, 30-d mortality, and composite endpoint in White patients and Black patients stratified by age and type of HF.

The unadjusted risk of 30-d readmissions and the composite endpoint was higher in Black compared with White patients whether stratified by age or type of HF. The unadjusted risk of 30-d mortality was higher in Black compared with White patients older than age 65 years, and higher in Black compared with White patients. *p<0.05, **p<0.01, ***p<0.001.
Figure 2. Percentage of patients residing in each quartile of the social deprivation index according to racial group.

The figure shows the distribution of Black and White patients within each unit of the SDI. For example, <1% of Black patients resided in census tracts with SDI score 0–3 while 3.5% of White patients resided in census tracts with an SDI score of 0–2. Because the residential distribution of Black patients is overlaid on the distribution of White patients, the mauve color represents the percentage of black patients in census tracts in which there is a larger percentage of White patients. SDI, Social Deprivation Index
Figure 3A. Excess 30-d HF Readmissions in Black Patients Compared with White Patients

Risk Difference in 30-d HF Readmission (ref=White)

Neighborhood Deprivation Quartile

Demographics Adjusted

Fully Adjusted
Figure 3B. Excess 30-d Deaths in Black Patients Compared with White Patients

Risk Difference in 30-d Deaths (ref=White)

0% 5% 10% 15%

Lowest Deprivation  Q2  Q3  Highest Deprivation

-0.3% 0.3% 1.3% 2.5% 1.1% 1.1% 2.2% 3.2%

Neighborhood Deprivation Quartile

Demographics Adjusted  Fully Adjusted
Figure 3C. Excess 30-d Composite Readmission/Death in Black Patients Compared with White Patients

The figure shows absolute risk differences between blacks and whites (reference) in each outcome by quartile of the Social Deprivation Index. The demographics adjusted risk difference accounts for age, sex, insurance, hospital location and year of index hospitalization; the fully adjusted risk difference further accounts for HF type, hypertension, diabetes, coronary artery disease, chronic kidney disease, atrial fibrillation, chronic pulmonary disease, peripheral vascular disease, systolic blood pressure, heart rate, respiration, estimated glomerular filtration rate, blood urea nitrogen, hemoglobin, and sodium, and discharging specialty. HF, Heart Failure; Q2, Quartile 2; Q3, Quartile 3

Figure 3. Excess risk of 30-d HF readmission (A), 30-d mortality (B), and composite endpoint (C) in Black compared with White patients hospitalized for acute heart failure.

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Table 1.
Baseline characteristics of the study cohort (at the time of the index hospitalization).

<table>
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<th>Characteristic</th>
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<th>Black patients N=16,147</th>
<th>P-value</th>
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<td>Age, years</td>
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<td>69 ± 15</td>
<td>64 ± 16</td>
<td>&lt;0.0001</td>
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<td>Age ≥ 65 years</td>
<td>17,533 (57.2)</td>
<td>9,630 (66.5)</td>
<td>7,903 (48.9)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Women</td>
<td>14,749 (48.2)</td>
<td>6,107 (42.2)</td>
<td>8,642 (53.5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Insurance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Private</td>
<td>6,050 (19.8)</td>
<td>3,178 (21.9)</td>
<td>2,872 (17.8)</td>
<td></td>
</tr>
<tr>
<td>• Medicare</td>
<td>20,480 (66.9)</td>
<td>10,126 (69.9)</td>
<td>10,354 (64.1)</td>
<td></td>
</tr>
<tr>
<td>• Medicaid</td>
<td>2,533 (8.3)</td>
<td>642 (4.4)</td>
<td>1,891 (11.7)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>HF classification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• HFrEF</td>
<td>14,356 (46.9)</td>
<td>6,584 (45.5)</td>
<td>7,772 (48.1)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>• HFpEF</td>
<td>7,532 (24.6)</td>
<td>3,560 (24.6)</td>
<td>3,972 (24.6)</td>
<td></td>
</tr>
<tr>
<td>• Other *</td>
<td>8,742 (28.5)</td>
<td>4,339 (30.0)</td>
<td>4,403 (27.3)</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>20,715 (67.6)</td>
<td>9,169 (63.3)</td>
<td>11,546 (71.5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Diabetes</td>
<td>12,596 (41.1)</td>
<td>5,179 (35.8)</td>
<td>7,417 (45.9)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Coronary Artery Disease</td>
<td>14,199 (46.4)</td>
<td>7,933 (54.8)</td>
<td>6,266 (38.8)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Chronic Kidney Disease</td>
<td>11,887 (38.8)</td>
<td>4,386 (30.3)</td>
<td>7,501 (46.5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>5,492 (17.9)</td>
<td>2,418 (16.7)</td>
<td>3,074 (19.0)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Atrial Fibrillation</td>
<td>9,562 (31.2)</td>
<td>6,040 (41.7)</td>
<td>3,522 (21.8)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Chronic Pulmonary Disease</td>
<td>10,510 (34.3)</td>
<td>5,156 (35.6)</td>
<td>5,354 (33.2)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Peripheral Vascular Disease</td>
<td>5,030 (16.4)</td>
<td>2,870 (19.8)</td>
<td>2,160 (13.4)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Charlson Comorbidity Index</td>
<td>4.3 ± 3.0</td>
<td>3.9 ± 2.9</td>
<td>4.6 ± 3.0</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Systolic blood pressure, mm Hg</td>
<td>140 ± 34</td>
<td>134 ± 29</td>
<td>145 ± 37</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Heart Rate, beats per minute</td>
<td>86 ± 25</td>
<td>83.3 ± 24</td>
<td>88.6 ± 26</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Respiratory rate, breaths per minute</td>
<td>20 ± 9</td>
<td>20 ± 10</td>
<td>20 ± 9</td>
<td>0.055</td>
</tr>
<tr>
<td>Creatinine, mg/dL</td>
<td>1.2 (0.9 – 1.8)</td>
<td>1.1 (0.9 – 1.5)</td>
<td>1.3 (1.0 – 2.2)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>eGFR, ml/min/1.73m²</td>
<td>60 ± 34</td>
<td>61 ± 30</td>
<td>59 ± 38</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Blood urea nitrogen, mg/dL</td>
<td>20 (14 – 32)</td>
<td>20 (15 – 30)</td>
<td>21 (14 – 34)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Total N=30,630</td>
<td>White patients N=14,483</td>
<td>Black patients N=16,147</td>
<td>P-value</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>----------------</td>
<td>------------------------</td>
<td>-------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Hemoglobin, g/dL</td>
<td>11.7 ± 2.4</td>
<td>12.0 ± 2.3</td>
<td>11.5 ± 2.4</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Sodium, mEq/L</td>
<td>137.6 ± 4.4</td>
<td>137.3 ± 4.3</td>
<td>137.9 ± 4.4</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>B-type natriuretic peptide, pg/mL</td>
<td>437 (160 – 1,025)</td>
<td>417 (170 – 929)</td>
<td>460 (149 – 1,127)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Troponin L, pg/mL</td>
<td>0.05 (0.01 – 0.16)</td>
<td>0.04 (0.01 – 0.19)</td>
<td>0.05 (0.02 – 0.14)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Medical therapy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• ACEi/ARB</td>
<td>14,640 (47.8)</td>
<td>6,160 (42.5)</td>
<td>8,480 (52.5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>• Beta-blocker</td>
<td>22,617 (79.2)</td>
<td>10,770 (79.4)</td>
<td>11,847 (79.1)</td>
<td>0.54</td>
</tr>
<tr>
<td>• Aldosterone antagonist</td>
<td>3,694 (12.9)</td>
<td>1,737 (12.8)</td>
<td>1,957 (13.1)</td>
<td>0.51</td>
</tr>
<tr>
<td>• Hydralazine-nitrates</td>
<td>1,384 (4.8)</td>
<td>295 (2.2)</td>
<td>1,089 (7.3)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>• Digoxin</td>
<td>2,673 (9.4)</td>
<td>1,601 (11.8)</td>
<td>1,072 (7.2)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Discharging specialty</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>• Cardiovascular</td>
<td>11,853 (38.7)</td>
<td>7,521 (51.9)</td>
<td>4,332 (26.8)</td>
<td></td>
</tr>
<tr>
<td>• Internal Medicine</td>
<td>14,863 (48.5)</td>
<td>4,927 (34.0)</td>
<td>9,936 (61.5)</td>
<td></td>
</tr>
<tr>
<td>• Other</td>
<td>3,914 (12.8)</td>
<td>2,035 (14.1)</td>
<td>1,879 (11.7)</td>
<td></td>
</tr>
<tr>
<td>Location of admission</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>• EUH Floor</td>
<td>11,091 (36.2)</td>
<td>6,422 (44.3)</td>
<td>4,669 (28.9)</td>
<td></td>
</tr>
<tr>
<td>• EUH ICU</td>
<td>4,491 (14.7)</td>
<td>2,717 (18.8)</td>
<td>1,774 (11.0)</td>
<td></td>
</tr>
<tr>
<td>• EUHM Floor</td>
<td>12,323 (40.2)</td>
<td>4,337 (29.9)</td>
<td>7,986 (49.5)</td>
<td></td>
</tr>
<tr>
<td>• EUHM ICU</td>
<td>2,725 (8.9)</td>
<td>1,007 (7.0)</td>
<td>1,718 (10.6)</td>
<td></td>
</tr>
<tr>
<td>Length of stay, days</td>
<td>6 (3–10)</td>
<td>6 (3–11)</td>
<td>5 (3–10)</td>
<td>0.0123</td>
</tr>
<tr>
<td>Social deprivation index score</td>
<td>61.3 (27.6)</td>
<td>48.6 (26.6)</td>
<td>72.7 (23.1)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Values are mean ± standard deviation, median (interquartile range), or N (%). ACEi, angiotensin converting enzyme inhibitor; ARB, angiotensin II receptor blocker; eGFR, estimated glomerular filtration rate; EUH, Emory University Hospital; EUHM, Emory University Hospital Midtown; HFrEF, heart failure with reduced ejection fraction; HFpEF, heart failure with preserved ejection fraction; ICU, intensive care unit.

* HF other refers to ICD-9 and ICD-10 codes including HF unspecified, right heart failure, and high output HF.
† Data missing for >10% of subjects.
‡ Medical therapy is based on the medications present at admission at the time of the index hospitalization.
Table 2.

Frequency of clinical events over study period by race.

<table>
<thead>
<tr>
<th>Event</th>
<th>Total N=30,630</th>
<th>White patients N=14,483</th>
<th>Black patients N=16,147</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total hospitalizations per patient</td>
<td>2.1 ± 2.4</td>
<td>1.7 ± 1.6</td>
<td>2.4 ± 2.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>30-d HF readmission</td>
<td>5,273 (17.2)</td>
<td>1,953 (13.5)</td>
<td>3,320 (20.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Any death</td>
<td>6,774 (22.1)</td>
<td>3,320 (22.9)</td>
<td>3,454 (21.4)</td>
<td>0.001</td>
</tr>
<tr>
<td>30-d death</td>
<td>3,859 (12.6)</td>
<td>1,767 (12.2)</td>
<td>2,092 (13.0)</td>
<td>0.047</td>
</tr>
</tbody>
</table>

Values are mean ± standard deviation, or N (%).
Table 3.
Risk ratios associated with 30-d HF readmission, 30-d mortality, and composite endpoint in Black versus White patients with acute heart failure.

<table>
<thead>
<tr>
<th></th>
<th>Unadjusted RR (95% CI)</th>
<th>Model 1 RR (95% CI)</th>
<th>Model 2 RR (95% CI)</th>
<th>Model 3 RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-d HF readmission</td>
<td>1.54 (1.47–1.63) ***</td>
<td>1.51 (1.43–1.59) ***</td>
<td>1.47 (1.39–1.56) ***</td>
<td>1.45 (1.37–1.54) ***</td>
</tr>
<tr>
<td>30-d All-cause mortality</td>
<td>1.11 (1.05–1.18) **</td>
<td>1.20 (1.13–1.28) ***</td>
<td>1.24 (1.17–1.33) ***</td>
<td>1.17 (1.10–1.25) ***</td>
</tr>
<tr>
<td>Composite of 30-d readmission or mortality</td>
<td>1.32 (1.27–1.37) ***</td>
<td>1.33 (1.28–1.39) ***</td>
<td>1.34 (1.29–1.40) ***</td>
<td>1.30 (1.24–1.35) ***</td>
</tr>
</tbody>
</table>

* p<.05,  ** p<.01,  *** p<.001

Model 1: adjusts for age, sex, insurance, hospital location, and year of index hospitalization;
Model 2: adjusts for Model 1 + HF type, hypertension, diabetes, coronary artery disease, chronic kidney disease, atrial fibrillation, chronic pulmonary disease, peripheral vascular disease, systolic blood pressure, heart rate, respiration, estimated glomerular filtration rate, blood urea nitrogen, hemoglobin, and sodium;
Model 3 adjusts for Model 1 and 2 + discharging specialty.

RR indicates risk ratio, CI indicates confidence interval.