6-13-2023

Neighbourhood-Level Social Deprivation and the Risk of Recurrent Heart Failure Hospitalizations in Type 2 Diabetes

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Recommended Citation

Deo SV, Al-Kindi S, Motairek I, et al.Neighbourhood-level social deprivation and the risk ofrecurrent heart failure hospitalizations in type 2 diabetes.Diabetes Obes Metab. 2023;25(10):2846-2852. doi:10.1111/dom.15174

Received: 4 May 2023 | Revised: 26 May 2023 | Accepted: 27 May 2023

DOI: 10.1111/dom.15174

ORIGINAL ARTICLE

WILEY

Neighbourhood-level social deprivation and the risk of recurrent heart failure hospitalizations in type 2 diabetes

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Funding information
National Institute on Minority Health and Health Disparities, Grant/Award Number: P50MD017351

Abstract

Background: The importance of type 2 diabetes mellitus (T2D) in heart failure hospitalizations (HFH) is acknowledged. As information on the prevalence and influence of social deprivation on HFH is limited, we studied this issue in a racially diverse cohort.

Methods: Linking data from US Veterans with stable T2D (without prevalent HF) with a zip-code derived population-level social deprivation index (SDI), we grouped them according to increasing SDI as follows: SDI: group I: ≤20; II: 21-40; III: 41-60; IV: 61-80; and V (most deprived) 81-100. Over a 10-year follow-up period, we identified the total (first and recurrent) number of HFH episodes for each patient and calculated the age-adjusted HFH rate [per 1000 patient-years (PY)]. We analysed the incident rate ratio between SDI groups and HFH using adjusted analyses.

Results: In 1 012 351 patients with T2D (mean age 67.5 years, 75.7% White), the cumulative incidence of first HFH was 9.4% and 14.2% in SDI groups I and V respectively. The 10-year total HFH rate was 54.8 (95% CI: 54.5, 55.2)/1000 PY. Total HFH increased incrementally from SDI group I [43.3 (95% CI: 42.4, 44.2)/1000 PY] to group V [68.6 (95% CI: 67.8, 69.9)/1000 PY]. Compared with group I, group V patients had a 53% higher relative risk of HFH. The negative association between SDI and HFH was stronger in Black patients (SDI × Race $p_{interaction} < .001$).

Conclusions: Social deprivation is associated with increased HFH in T2D with a disproportionate influence in Black patients. Strategies to reduce social disparity and equalize racial differences may help to bridge this gap.

KEYWORDS
heart failure, social deprivation, type 2 diabetes

1 | INTRODUCTION

Type 2 diabetes mellitus (T2D) is a well-known risk factor for heart failure (HF). T2D is associated with a two- to three-fold increase in

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HF risk.[1] Many factors, such as age, gender, race/ethnicity and lifestyle behaviours such as unhealthy diet and physical inactivity, enhance the risk of HF in patients with T2D. Previous studies have already shown that a deprived socioeconomic status is associated with higher rates of both T2D and HF.[2,3] In fact, research from Europe reported that neighbourhood social deprivation is also associated with higher rates of T2D-related complications such as neuropathy, nephropathy and retinopathy.[4,5] While data from Southern Community Cohort study showed a 12% increase in incident HF for every quartile increase in the social deprivation index (SDI),[6] this was limited to a small geographical location and a short follow-up (median 5 years). Another study in patients with acute decompensated HF reported increased 30-day HF readmission and 30-day mortality in patients admitted with acute HF.[7] However, information on how social deprivation influences HF hospitalization (HFH) in patients with T2D is limited. Understanding this may allow for more careful evaluation of at-risk T2D individuals. This may further translate into improved utilization of newer cardio-protective agents [sodium-glucose cotransporter 2 inhibitors (SGLT2is), glucagon-like peptide 1 receptor agonist] as well as traditional HF therapies including device implantation.[8] Accordingly in this study we investigated the association between residential-level social deprivation and HFH in patients with T2D in the United States. We further evaluated the interaction between social deprivation, race and ethnicity.

2 | METHODS

2.1 | Overview of the cohort

The Veterans Affairs (VA) health care system is the largest single health care provider of in- and outpatient care to almost 9 million US Veterans. We used the Corporate Data Warehouse (CDW) as the primary data source for our study. The CDW is a central secure repository of information obtained from the electronic health records of US Veterans. Apart from containing clinical, laboratory and procedural information, researchers can link all these data together using a unique patient identifier and obtain a very accurate trajectory of encounter episodes for each patient. Information regarding clinical encounters occurring outside the VA health care system is also provided when this care is reimbursed by the VA. We initially identified US Veterans that received outpatient care with a diagnosis of T2D in 2010 across all VA health care locations and defined their first visit during this year as they index visit. We used a time-period of 365 days before the index visit to collect information regarding their clinical characteristics and laboratory results. For each patient, we collected the following information: age at index date, sex, duration of T2D (<1 year, between 1 and 3 years, >3 years), self-reported race (White, Black, others), self-reported ethnicity (Hispanic, non-Hispanic), and the following pre-existing clinical comorbidities: hypertension, obesity, coronary artery disease (CAD), peripheral arterial disease (PAD), cerebrovascular disease (CeVD), chronic kidney disease (CKD), smoking status, dialysis dependence, chronic obstructive pulmonary disease, chronic liver disease and previous cancer. Patients with pre-existing CAD, PAD or CeVD were defined as having pre-existing atherosclerotic cardiovascular disease (ASCVD), CKD was defined as an estimated glomerular filtration rate <60 ml/min 1.73 m^2.

We identified the patients' residential zip code at the time of their index visit and as described below, used this information to determine the SDI.

2.2 | Endpoint

The primary endpoint for the study was the total (first and recurrent) number of HFHs over the follow-up period. We defined a HFH as being admitted or discharged with the primary diagnosis of HF as ascertained using codes from the International Classification of Diseases (ICD) 9th and 10th versions. To ensure that inter-facility transfers were not double counted, we considered a recurrent HFH episode if it occurred at least 7 days apart from an earlier episode. As the secondary endpoint we analysed the time to first HFH during the study period.

2.3 | Social deprivation index

The 2015 SDI is a composite metric of the population-level socioeconomic status derived at the zip code level.[9] This index is derived using summary data at a specific geographical level from seven domains included in the American Community Survey. These domains were identified by the creators of the SDI through factor analysis. The variables included in this SDI score are: household income [percent population less than 100% Federal Poverty Level (population under 0.99/total population)]; education [percent population 25 years or more with less than 12 years of education (population with less than high school diploma or 12 years of education/total population]; employment [percent non-employed (not in labour force + unemployed)/(civilian + not in the labour force) for the population 16-64 years]; housing [percent population living in renter-occupied housing units (renter occupied housing units)/(owner-occupied housing units + renter occupied housing units), percent population living in crowded housing units (tenure by occupants per room-a population with ≥1.01 occupants per room in owner-occupied housing units and renter occupied housing units)/total population); household characteristics {percent single-parent households with dependents <18 years [total single-parent households (male and female) with dependents <18 years)/total population]}; transportation [percent population with no car (population with no vehicle available/total population)]; and demographics [percent high needs population – (population under 5 years of age + women between the ages of 15 and 44 years + everyone 65 years and over)/total population]. The final SDI measure for each geographical area is a weighted total of all these measures and ranges from 0 (least socially deprived) to 100 (most socially deprived). For our study, we grouped patients using the quintile of the SDI: group I (least deprived): ≤20; group II: 21-40; group III: 41-60; group IV: 61-80; and group V (most deprived) 81-100 (Figure 1).

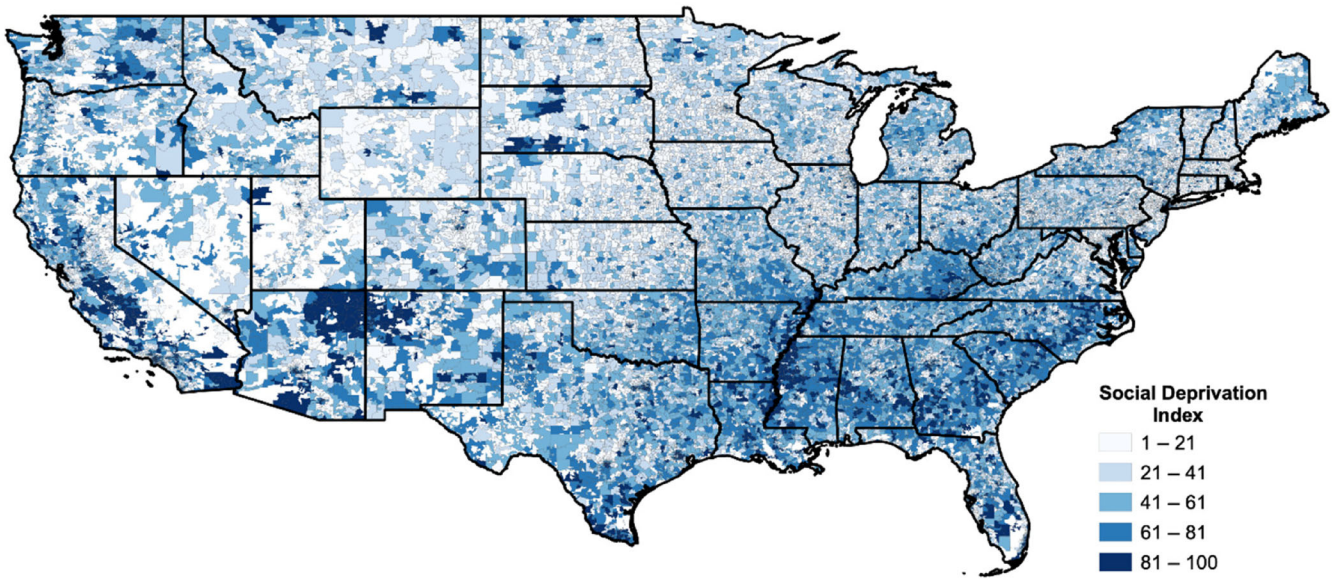

FIGURE 1 Map of the social deprivation index distribution according to zip codes in the United States. This map presents the social deprivation index according to zip codes in the United States.

2.4 | Statistical analyses

We reported continuous and categorical data as mean (standard deviation) or n (%) respectively. We obtained summary statistics for the baseline characteristics of our study cohort for each SDI group and compared results between groups I and V with the two-tailed t-test and X^2 test for continuous and categorical data respectively. We initially calculated the cumulative incidence of the first HFH, overall and according to the SDI groups using a competing risk model accounting for mortality as the competing event. To evaluate the association between the SDI and the time to first HFH, we fit a generalized linear regression model (using time as an offset variable) and included the SDI category variable as the main covariate and adjusted for sex, age, race, ethnicity, duration of diabetes, pre-existing ASCVD and pre-existing CKD. From this model we reported the relative risk of experiencing the first HFH for each SDI group using group I as the reference. We then obtained the total (first and recurrent) number of HFH for each patient and calculated the age adjusted total 10-year HFH rate (per 1000 patient-years [PY]) for the whole cohort, separately for each SDI group, and according to race, sex, ethnicity and baseline clinical characteristics (pre-existing ASCVD, pre-existing CKD). To evaluate the association between the SDI and the total number of HFH episodes experienced during follow-up, we fit a generalized linear regression model including the SDI category variable as the main covariate and adjusted for sex, age, race, ethnicity, duration of diabetes, pre-existing ASCVD and pre-existing CKD. As our outcome here was count data, we used a Poisson link and included the follow-up time as an offset term in the model. We report results of this model using incident rate ratios (IRR) with 95% confidence intervals (95% CI). To evaluate whether the association between SDI and total HFH was disproportionately different across to race and ethnicity, we fit identical generalized linear models with the Poisson distribution and follow-up time as an offset term and tested for the interaction of these covariates with SDI.

3 | RESULTS

We analysed data from 1 012 351 patients (mean age 67.5 years, 2.9% women, 75.7% White) that received outpatient care for T2D in 2010 at VA medical centres nationwide. Recent T2D (<1 year) was present in 24.2%, and 57.6% had T2D for >3 years. The prevalence of pre-existing CAD, PAD, CeVD and CKD was 31.4%, 15.0%, 11.2% and 13.2% respectively. The distribution of patients in SDI groups I, II, III, IV and V was 14%, 20%, 23%, 24% and 19% respectively. Compared with SDI group I, the proportion of Black (5.9% vs. 38.8%) and Hispanic (2.3% vs. 9.5%) patients was substantially higher in group V. The prevalence of CAD (I: 34.7% vs. V: 26.4%) was lower in SDI group V, while that of CeVD (I: 10.8% vs. V: 11.6%) and CKD (I: 12.6% vs. V: 14.5%) was higher (Table S1).

Over a 11.6 years (maximum 12.7 years) median follow-up (9 458 596 PY), death occurred in 493 726 (48.8%) and HFH in 152 065 (15.0%) patients. Accounting for mortality, the cumulative incidence of first HFH was 11.8 (95% CI: 11.7, 11.9)%. The cumulative incidence of first HFH in SDI groups I, II, III, IV and V was 9.4%, 107%, 11.7%, 12.6% and 14.2% respectively. Compared with SDI group I, groups II [risk ratio (RR) 1.06 (95% CI: 1.05, 1.07)], III [RR 1.11 (95% CI: 1.10, 1.12)], IV [RR 1.15 (95% CI: 1.14, 1.16)] and V [RR 1.24 (95% CI: 1.23, 1.26)] had a significantly higher risk of experiencing the first HFH (Table S2). We observed 456 604 HFH events during the study period and the cumulative 10-year age-adjusted HFH rate was 54.8 (95% CI: 54.5, 55.2)/1000 PY. Patients in SDI group V (most deprived)

[68.6 (95% CI: 67.8, 69.9)/1000 PY] had substantially higher HFH rates than in SDI group I (least deprived) [43.3 (95% CI: 42.4, 44.2)/1000 PY] (Figure 2). Black patients [63.3 (95% CI: 62.2, 64.5)/1000 PY] had substantially higher 10-year HFH rates than White people [53.6 (53.2, 54.1)/1000 PY]. Men [55.5 (55.1, 55.9)/1000 PY] had higher rates than women did [37.2 (35.3, 39.1)/1000 PY].

In the 152 065 patients that experienced HFH during the study period, 62.9%, 23.1% and 14% had less than three, three to five and more than five HFH episodes (Figure 3A). Overall, compared with SDI group I, SDI group V had more patients with more than five HFH episodes (16.1% vs. 12.8%) (Figure 3B). Compared with White patients, more Black patients (17.5% vs. 12.3%) had more than five HFH episodes, while the incidence of more than five HFH episodes was comparable in both men and women (13.8% vs. 13.9%) (Table S3). Compared with white patients, in both SDI groups I and V, the proportion of patients with more

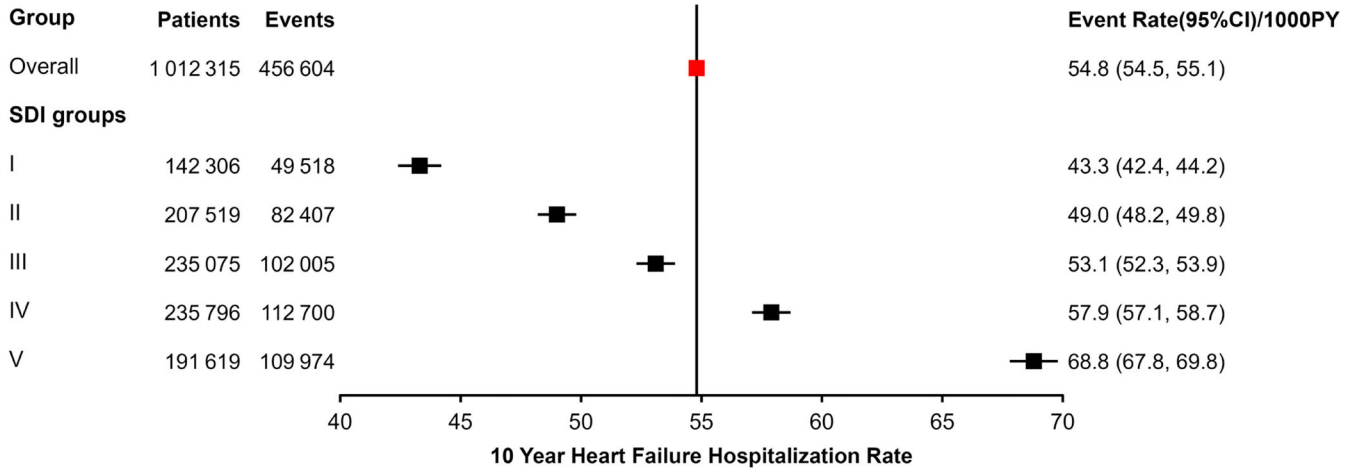

FIGURE 2 Ten-year total (first and recurrent) heart failure hospitalization rate. This forest plot presents the 10-year total (first and recurrent) heart failure hospitalization rate (per 1000 PY) in our study cohort. PY, patient-years; SDI, social deprivation index.

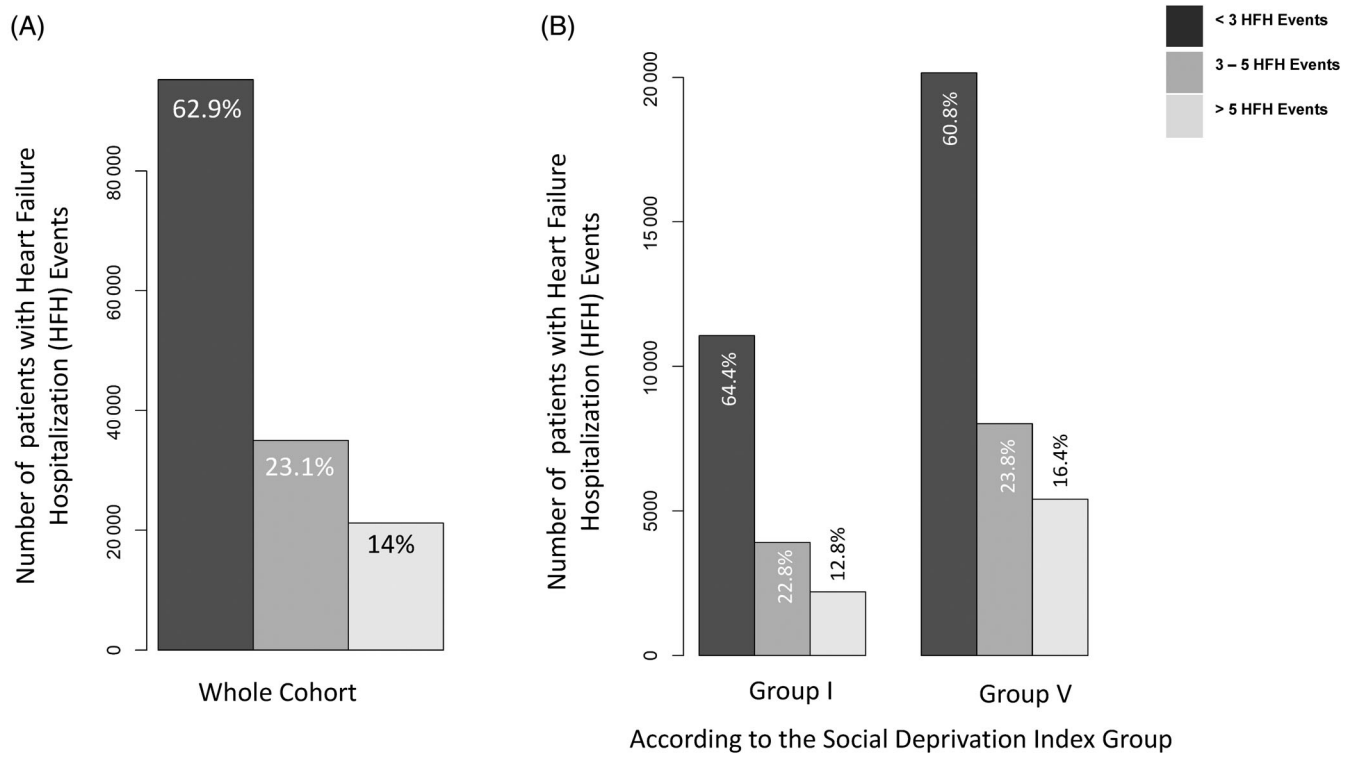

FIGURE 3 Frequency of heart failure hospitalization (HFH) events in the whole cohort and according to the social deprivation index. This bar plot provides information regarding the frequency of HFH events in those patients that had at least one HFH event. We present results for the whole cohort and in social deprivation index groups I (least deprived) and V (most deprived).

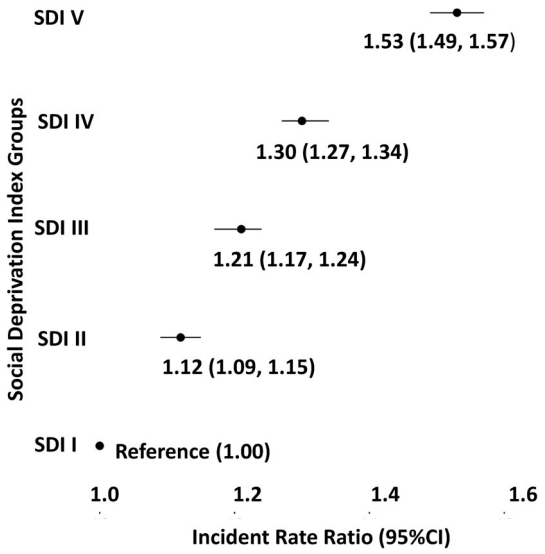

FIGURE 4 Association between social deprivation index (SDI) groups and total heart failure hospitalization events over the study period. This figure presents the relative risk for total (first and recurrent) heart failure hospitalizations according to the social deprivation index. The model was adjusted for to race, sex, ethnicity, pre-existing atherosclerotic cardiovascular disease and pre-existing chronic kidney disease.

than five HFH episodes was substantially higher among Black patients.

In adjusted analysis, compared with SDI group I, the risk for recurrent HFH increased with each subsequent SDI group, with patients in SDI group V having a 53% higher risk for recurrent HFH [IRR 1.53 (1.49, 1.57); $p < .001$] (Figure 4). Compared with White patients, Black patients [IRR 1.97 (1.05, 1.10); $p < .001$] had a higher risk of recurrent HFH, as did patients with pre-existing ASCVD [IRR 2.03 (2.00, 2.06)] or CKD [IRR 1.73 (1.70, 1.77)]. The risk for HFH was lower in women [IRR 0.73 (0.69, 0.77)] compared with men and, in Hispanics [IRR 0.89 (0.86, 0.92)] compared with non-Hispanic patients. The relative risk for HFH with an increasing SDI was disproportionately higher for Black vs. white patients ($p_{interaction} < .001$) and slightly higher in women than men ($p_{interaction} < .001$) (Table S4).

4 | DISCUSSION

Using data from >1 million patients with T2D receiving outpatient care at VA medical centres nationally in the United States, we observed that increasing levels of neighbourhood deprivation were associated with a higher risk for recurrent HFH events. Furthermore, we observed that, for the same levels of social deprivation, the risk of recurrent HFH is disproportionately higher among Black patients. Finally, compared with the least deprived patients, we observed that the incidence of experiencing three to five HFH and more than five HFH events over the 10-year study period was significantly higher among the most deprived patients.

Data suggest that, compared with people with T2D living in affluent neighbourhoods, those living in deprived areas have a higher prevalence of traditional cardiovascular disease risk factors.[10] There is already evidence that social deprivation is associated with increased HF risk, and that this association may be stronger in patients with T2D. A Southern Community Cohort study with 27 078 patients, with more than 50% residing in deprived neighbourhoods, reported that an interquartile increase in the neighbourhood deprivation index was associated with a 12% increase in the risk of incident HF.[6] In a previous study, we showed that, in the United States, neighbourhood-level social vulnerability and historical residential segregation policies were associated with higher prevalence of cardiovascular disease.[2,11] However, to date, we found that only one study has specifically examined the relationship between social deprivation and HF risk in patients with type 2 diabetes. In a community-level analysis of 434 000 Swedish residents, the risk of incident HF was 11% higher in deprived neighbourhoods.[12] Our patients were younger than that reported by this Swedish study, possibly because US Veterans often have a higher burden of comorbidities compared with the general population and therefore develop incident disease at earlier ages. However, apart from this difference, our study using US national data supports previous evidence and builds on it to show the disproportionate impact of social deprivation in Black patients with T2D. In our study, we evaluated the burden of HFH and therefore did not capture outpatient incident HF. While incident HF is also important to identify, socially deprived patients have a lower access to timely diagnostic pathways resulting in more HFH events rather than stable incident HF. Hence, improved access to screening pathways may help to reduce the burden of HFH for patients in SDI groups IV and V. In fact, the percentage of patients having more than five HFH was substantially higher in SDI group V versus group I (16% vs. 12%). This therefore further highlights the fact that, even after the first HFH, SDI group V patients failed to receive appropriate risk mitigation therapies.

There are several known explanations linking neighbourhood deprivation and increased cardiovascular risk. However, in addition to issues related to limited access to health care,[13] financial toxicity,[14] food insecurity[15] and lack of resources, it is also possible that there are differences in knowledge, attitudes and beliefs among socioeconomic groups that may lead to variations in lifestyles, particularly among the more vulnerable such as people with T2D. Thus, there is need to investigate the importance of neighbourhood factors (as mediators, risk enhancers, or modifiers) in the prediction of cardiovascular risk in patients with T2D. Increased social deprivation may additionally result in the lower utilization of cardioprotective T2D therapies. A large Medicare study of 4 057 725 individuals reported that social deprivation was associated with a 4% reduced likelihood of SGLT2i/glucagon-like peptide 1 receptor agonist use.[16] These findings, in conjunction with our study, carry important implications for pharmaco-equity and its impact on projected risks. As SDI is concurrently associated with both increased HF events and lower SGLT2i use, this trend is expected to worsen HF disparities related to socioeconomic status over the next decades. As such, there is an urgent

need for strategies to improve pharmaco-equity. In addition to novel care delivery models (e.g. community health workers),[17] collaborative delivery models are urgently needed to ensure health equity in socially deprived individuals that have the highest risk for HFH.[9,18]

To our knowledge, this is the largest and the first US-based study to examine the association between neighbourhood social deprivation and recurrent HFH in patients with T2D. However, our results should be considered on the background of certain limitations. Patients from the VA health care system are generally older with a higher burden of co-morbidities; therefore, our absolute event rates may be higher than that observed in other cohorts. However, we believe that the differential impact of neighbourhood deprivation is unlikely to change. Our cohort was predominantly men. While we observed a substantially lower HFH rate among women, these results need to be corroborated, as women comprise only 3% of our study cohort. Our study is based on electronic health records. We used ICD codes to define HFH and therefore may also be subject to misclassification. However, this is unlikely to impact the incrementally increasing relative risk that we observed between higher social deprivation and recurrent HFH. Lastly, the social deprivation measures that we have used in this study were calculated at the population-level rather than at the individual patient level. While we agree that some individual variation probably exists between patients residing in the same zip code, using publicly available information may make our results more generalizable to other cohorts. Our study also has several strengths. First, by using longitudinal data from the VA, we were able to obtain an accurate trajectory of clinical encounters for each patient, identify non-VA admissions and analyse recurrent HFH events rather than only time to first event. Secondly, including more than 1 million patients all over the United States increases patient heterogeneity and increases study generalizability. Finally, with a median follow-up of 12 years and minimal censoring, our study can capture recurrent HFH events effectively.

In conclusion, neighbourhood social deprivation is associated with increased HFH in patients with T2D. These results suggest that addressing social and economic factors in deprived neighbourhoods may be a potential strategy for reducing the HFH in patients with T2D. In addition, the incorporation of neighbourhood factors in risk prediction models needs further investigation.

ACKNOWLEDGEMENTS

The views expressed in this article are those of the authors. They do not represent the position or policy of the Department of Veteran Affairs or the United States Government.

FUNDING INFORMATION

This work was partly funded by the National Institute on Minority Health and Health Disparities Award no. P50MD017351.

CONFLICT OF INTEREST STATEMENT

Naveed Sattar reports personal fees from Afimmune, Amgen, AstraZeneca, Boehringer Ingelheim, Eli Lilly, Hanmi Pharmaceuticals, Merck Sharp & Dohme, Novartis, Novo Nordisk, Pfizer, and Sanofi and grant funding paid to his university from AstraZeneca, Boehringer Ingelheim, Novartis, and Roche Diagnostics outside the submitted work. Other authors do not have any potential conflicts of interest.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/dom.15174.

DATA AVAILABILITY STATEMENT

Data used in this study can be obtained by researchers from the Department of Veterans Affairs using the regular channels for research approval. Further details regarding the statistical methods used are provided in the supplement and the R code used for analyses is available at: https://github.com/svd09/dm_hfh_sdi.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Deo SV, Al-Kindi S, Motairek I, et al. Neighbourhood-level social deprivation and the risk of recurrent heart failure hospitalizations in type 2 diabetes. *Diabetes Obes Metab*. 2023;25(10):2846-2852. doi:10.1111/dom.15174