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MAJOR ARTICLE

Association of Neighborhood Deprivation With Healthcare Utilization Among Persons With Human Immunodeficiency Virus: A Latent Class Analysis

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Background. We previously identified 3 latent classes of healthcare utilization among people with human immunodeficiency virus (PWH): adherent, nonadherent, and sick. Although membership in the "nonadherent" group was associated with subsequent disengagement from human immunodeficiency virus (HIV) care, socioeconomic predictors of class membership remain unexplored.

Methods. We validated our healthcare utilization–based latent class model of PWH receiving care at Duke University (Durham, North Carolina) using patient-level data from 2015 to 2018. SDI scores were assigned to cohort members based on residential addresses. Associations of patient-level covariates with class membership were estimated using multivariable logistic regression and movement between classes was estimated using latent transition analysis.

Results. A total of 1443 unique patients (median age of 50 years, 28% female sex at birth, 57% Black) were included in the analysis. PWH in the most disadvantaged (highest) SDI decile were more likely to be in the "nonadherent" class than the remainder of the cohort (odds ratio [OR], 1.58 [95% confidence interval {CI}, .95–2.63]) and were significantly more likely to be in the "sick" class (OR, 2.65 [95% CI, 2.13–3.30]). PWH in the highest SDI decile were also more likely to transition into and less likely to transition out of the "sick" class.

Conclusions. PWH who resided in neighborhoods with high levels of social deprivation were more likely to have latent class membership in suboptimal healthcare utilization groupings, and membership persisted over time. Risk stratification models based on healthcare utilization may be useful tools in the early identification of persons at risk for suboptimal HIV care engagement.

Keywords. HIV; engagement in HIV care; healthcare utilization; latent class analysis; Social Deprivation Index.

Strategies to retain people with human immunodeficiency virus (PWH) in care are crucial to reductions in human immunodeficiency virus (HIV) morbidity and mortality [1]. Regular engagement in HIV care facilitates viral suppression, which is associated with both improvement in individual health outcomes and decreased HIV transmission [2, 3]. There has been an extensive effort among researchers and governmental agencies to implement a well-designed process-based approach to getting PWH from diagnosis to viral suppression—achieved only by regular engagement—to improve clinical outcomes in PWH [4].

As a consequence, there is an extensive literature focused on the identification of patients more likely to disengage from care and/or have poor clinical outcomes. Most of these studies examine nonmodifiable demographic risk factors (race/ethnicity, age, sex), comorbidities (substance abuse), self-reported living conditions (rent/own, staying with a friend, homeless shelter), or HIV-related behaviors (HIV clinic nonattendance, nonadherence with antiretroviral therapy [ART]) as predictors of HIV care disengagement and poor clinical outcomes [5–9]. Examining healthcare utilization in PWH provides unique insight by focusing on easily measurable patient behaviors instead of difficult-to-modify structural determinants mostly beyond the sphere of influence of healthcare professionals. In previous work, we used latent class analysis (LCA), a modeling methodology used to aggregate observations into groupings based on responses to a set of categorical variables, to identify 3 distinct patterns of non-HIV-specific healthcare utilization among a cohort of persons with HIV who received HIV care within a university-based clinic in the southern United States (US); the 3 classes were labeled for simplification as "adherent," "nonadherent," and "sick" [10]. Using these classes based on healthcare utilization patterns alone, we found that persons

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in the nonadherent class were 23 times more likely to disengage from HIV care completely the following year than the rest of the study cohort [1]. Building upon our previous work, we present an analysis with 2 objectives: (1) to conduct an internal validation of our previously derived healthcare use–based latent classes on a more contemporary cohort and (2) to explore how social determinants of health contribute to the segregation in healthcare use patterns by evaluating the association of neighborhood-level environmental factors, captured by the Social Deprivation Index (SDI) score, with membership in our previously determined latent classes [11].

METHODS

Study Population

We included all PWH (age ≥18 years) with ≥1 HIV care visit at the Duke University Adult Infectious Diseases (ID) clinic between 1 January 2015 and 31 December 2018. People were followed until administrative censoring at the end of the study period or death. Demographic and clinical patient-level covariates were abstracted from the electronic health record (EHR) using the Duke Enterprise Data Unified Content Explorer (DEDUCE), a data interface that allows for query of patient-level data from all clinical encounters within the Duke University Health System since 1996 [12]. The Duke ID clinic provides medical care to approximately 2000 adults living with HIV (58% Black, 28% female sex at birth, median age 51 years). All activities for this study were approved by the Duke University Institutional Review Board.

Healthcare Utilization Classes

We estimated a latent class model based on healthcare utilization indicators (emergency department [ED] visits, clinic attendance, hospital admissions, and HIV viral suppression defined as viral load <400 copies/mL on each check during the study period) in order to validate the latent class model previously derived for PWH for the years 2009–2013 [1]. We defined viral suppression as viral load of <400 copies/mL to remain consistent with the lower limit of quantification for the HIV-1 RNA quantification assay available at the earliest date of the study observation period. Viral suppression for latent class purposes was measured over the course of the index 12 months of observation. Three classes of healthcare utilization were identified from the prior model: "adherent" (attended at least 1 HIV clinic visit in each half of the index calendar year, <2 ED visits per year, no inpatient admissions, and virologically suppressed); "nonadherent" (did not regularly attend HIV clinic visits each half of the index calendar year, ≥2 ED visits per year, 0–1 inpatient admissions per year per patient, and at least 1 detectable viral load >400 copies/mL in the index year); and "sick" (attended HIV clinic visits each half of index calendar year, ≥2 ED visits per year, ≥1 inpatient admission per year, and virologically suppressed).

Social Deprivation Index

The SDI is a composite measure of deprivation based on the proportions of people living in a given area with each of 7 demographic characteristics: living in poverty, ≤12 years of education, single-parent household, living in rented housing unit, living in overcrowded housing unit, living in a household without a car, and nonemployed adults <65 years of age. These characteristics were collected as part of the American Community Survey and used to quantify the socioeconomic variation in health outcomes. The SDI measure is calculated at 4 geographic levels (census tract, ZIP code [ie, postal code] tabulation area, primary care service area, and counties), and was last updated in 2015. The composite score ranges from 0 (least disadvantaged) to 100 (most disadvantaged) [11]. SDI scores were assigned to each patient for the 2015–2018 years using their EHR-documented address of residence for that calendar year, based on the ZIP code tabulation area covering the address of interest. For patients with ≥ 1 address during a given calendar year, a duration-weighted mean SDI score for all addresses documented in the EHR that year was derived. Persons without a documented address were excluded from the analysis (<3%).

Change of Residence Address Variable and Patient-Level Covariates

We created a variable for frequency of residence change during a given calendar year (0 = no change; 1 = changed once during calendar year; 2 = ≥2 changes during calendar year). We hypothesized that this variable would serve as a surrogate for housing instability (and perhaps overall socioeconomic instability). For individuals who lived in ≥ 1 residence address within a year, we averaged the SDI value assigned to every residence address reported in that year. To assess the association of patient demographics with class membership and transition between classes over time, we also included natal sex, race (dichotomized as Black vs non-Black), and age (dichotomized as <40 years and ≥40 years at study entry) in the multivariable analysis.

Statistical Analysis

Latent classes were estimated using PROC LCA in SAS software [13]. To find the optimal number of latent classes in our model, we estimated models including 2–5 latent classes to assess model fit. Model identification for each solution was assessed by an expectation-maximization algorithm and set to a maximum of 10 000 iterations. The Bayesian information criteria (BIC) and Akaike information criterion (AIC) were used to determine the best model in terms of the balance between fit and parsimony [14].

Finally, patients were assigned to the class for which they had the highest posterior probability of membership. To study the association among demographic characteristics and class membership, we estimated a multivariable multinomial logistic

regression model within PROC LCA. The model simultaneously estimated the posterior probability of membership in a given class and the odds of class membership associated with specified sociodemographic characteristics [15].

To examine movement between classes over time, we conducted a latent transition analysis [10]. We calculated the transition probability as the proportion of patients who transitioned from class X at time T to class Y at time T + 1 where X and Y ∈ = [adherent, nonadherent, sick] and T∈ = [2015, 2016, 2017]. We averaged the probability of transition between each of the 3 annual intervals (2015–2016, 2016–2017, 2017–2018), to calculate a composite probability of class transition for each observation. To compare transition probabilities between latent classes among cohort subsets, we calculated transition probability ratios (probability within subset/probability of cohort referent) between groups.

RESULTS

Cohort Characteristics and Latent Class Description

Overall, 1443 unique patients met eligibility criteria; the median patient age was 50 years, 28% were female, and 57% were Black (Table 1). A 3-latent class model was found to be best in terms of balance between fit and parsimony (aggregate AIC, 156.10; aggregate BIC, 310.52) (Supplementary Table 1). In this cohort, 76% of patients were classified as adherent, 14% as sick, and 10% as nonadherent (Table 2). Response patterns of each of the 3 latent classes derived from this analysis were similar to the classes reported in our previous analysis: adherent, nonadherent, and sick [1] (Table 3).

SDI Distribution in Our Cohort and Across Classes

For 93% of our cohort we assigned the SDI score based on census tract of residence; for 7% of our patients the census tract was not available, so we assigned SDI based on a 5-digit ZIP code. The aggregate SDI score distribution (the histogram and the kernel density estimation) of the pooled data is left skewed with a long tail on the left side and a peak on the top values of the SDI score (mean, 61.9; median, 68.0; Supplementary Figure 1). The general shape of the SDI distribution when stratified by class is similar, with peaks farthest to the right for the sick class, followed by the nonadherent class, then the adherent class (highest SDI and poorest living conditions for the sick class).

Class Membership Likelihood (Multinomial Logistic Regression)

Overall, female patients were more likely to be in the nonadherent class (odds ratio [OR], 1.44 [95% confidence interval {CI}, 1.01–2.02]) and the sick class (OR, 1.58 [95% CI, 1.34–1.90]) than males. Whites were significantly less likely than non-White patients to be in the sick class (OR, 0.36 [95% CI, .29–.45]). Persons aged ≤40 years were also significantly more likely to be in the nonadherent class than older patients (OR, 2.88 [95% CI, 2.06–4.01]). Persons within the highest

Table 1. Baseline Analysis Cohort Characteristics, 2015

Characteristic	Cohort (N = 1443)
Age at study entry, y, median (IQR)	50 (41–57)
Female sex at birth	405 (28.0)
Race	
Black	820 (56.8)
White	514 (35.6)
Other[a]	109 (7.6)
Hispanic ethnicity	52 (3.6)
Social Deprivation Index, mean (SD)	62.0 (28.4)

Data are presented as No. (%) unless otherwise indicated.

Abbreviations: IQR, interquartile range; SD, standard deviation.

[a]Other race includes American Indian/Alaska Native, Asian/Pacific Islander, ≥2 races, or race not disclosed.

Table 2. Odds of Latent Class Membership, 2015–2018

Characteristic	Class I (Adherent) (n = 4425)[a]	Class II (Nonadherent) (n = 667)[a]	Class III (Sick) (n = 969)[a]
Female sex at birth	Ref	1.44 (1.01–2.02)	1.58 (1.34–2.90)
White	Ref	1.06 (.71–1.56)	0.36 (.29–.45)
Age (<40 y)	Ref	2.88 (2.06–4.01)	0.89 (.70–1.13)
SDI (top decile)	Ref	1.58 (.95–2.63)	2.65 (2.13–3.30)
> 1 residence during a year	Ref	1.12 (.44–2.88)	5.81 (4.05–8.35)

Data are presented as odds ratio (95% confidence interval).

Abbreviations: Ref, referent group; SDI, Social Deprivation Index.

[a]Total No. is greater than the number of unique patients because it represents number of individual observations during the period of interest (ie, 1 person could account for numerous observations if followed during multiple study years).

Table 3. Item Response by Latent Class, 2015–2018

Characteristic	Class I (Adherent) (n = 4425 [73%])[a]	Class II (Nonadherent) (n = 667 [11%])[a]	Class III (Sick) (n = 969 [16%])[a]
Emergency department visits per year, %			
0	94.7	90.4	4.6
1	5.2	6.7	35.4
≥2	<0.1	2.9	60
Inpatient admissions per year, %			
0	98.9	99.3	64.2
1	1	0.6	22
≥2	0.1	<0.1	13.8
Clinic visits in each half of the year, %			
Yes	75.4	16.4	77.2
No	24.6	83.6	22.8
Virologic suppression (<400 copies/mL), %			
Never	2.4	29.9	4.6
Sometimes	8.3	18.6	26.2
Always	89.3	51.5	69.2

[a]Total No. is greater than the number of unique patients because it represents number of individual observations during the period of interest (ie, 1 person could account for numerous observations if followed during multiple study years).

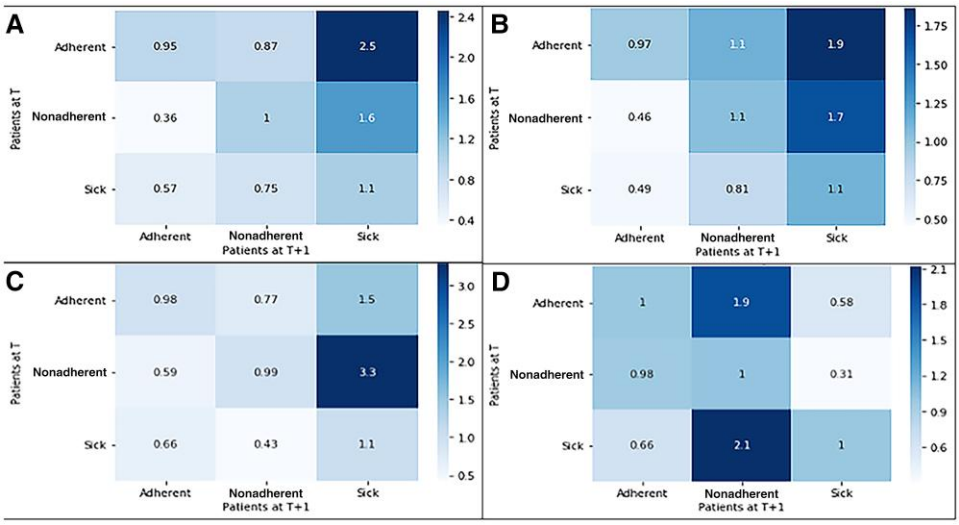

Figure 1. Latent transition analysis heatmap (N = 1443). The y-axis is patient class membership at year 0, and the x-axis is patient class membership at year +1. Embedded numbers indicate the odds ratio for transition from class T to class T + 1 compared to the referent group. *A*, Latent transition analysis for social deprivation index for participants with SDI > 90th percentile. *B*, Latent transition analysis for participants classified as Black race. *C*, Latent transition analysis for participants assigned female at birth. *D*, Latent transition analysis for participants age <40 years.

SDI score decile (worst socioeconomic conditions) demonstrated a strong trend toward increased likelihood of membership in the nonadherent latent class, although this trend did not meet statistical significance (OR, 1.58 [95% CI, .95–2.63]). Persons in the highest SDI decile were also significantly more likely to be a member of the sick class (OR, 2.65 [95% CI, 2.13–3.30]) than patients in lower SDI score deciles. Finally, participants who reported ≥2 addresses within the same year were significantly more likely to be in the sick class regardless of whether they moved to a residence with a lower or greater SDI score (OR, 5.81 [95% CI, 4.05–8.35]) (Table 2).

Transition Analysis

Patients in the highest SDI score decile were more likely to transition to the sick class, regardless of their initial class (OR, 2.5 for adherent; OR, 1.6 for nonadherent), and less likely to transition out of the sick class (OR, 0.57 for adherent; OR, 0.75 for nonadherent) than those in lower SDI deciles (Figure 1*A*). Black PWH were more likely than non-Black PWH to transition out of the adherent class to either the nonadherent (OR, 1.1) or sick (OR, 1.9) classes, and less likely to transition out of the sick class (OR, 0.49 for adherent; OR, 0.81 for nonadherent) (Figure 1*B*). Female patients were more likely to transition to the sick class, regardless of their initial class (OR, 1.5 for adherent; OR, 3.3 for nonadherent), and less likely to transition out of the sick class than men (Figure 1*C*). Finally, PWH <40 years of age were more likely to transition to the nonadherent class, regardless of their initial class (OR, 1.9 for adherent; OR, 2.1 for sick), and less likely to transition out of the nonadherent class (OR, 0.98 for adherent; OR, 0.31 for sick) than older PWH (Figure 1*D*).

DISCUSSION

We conducted a latent class and latent transition analysis of healthcare utilization patterns in approximately 1400 patients who received HIV care at the Duke Adult ID Clinic between 2015 and 2018. Our data suggest that PWH who lived in areas with high levels of social deprivation (highest decile SDI scores) were more likely to have initial membership in adverse health utilization classes (nonadherent and sick) than the rest of the study cohort. Furthermore, PWH who resided in locales with high levels of social deprivation were also more likely to transition from favorable health utilization classes (adherent) to adverse health utilization groups over time. We also found that transitions in housing, as represented by the residence transition variable, is also independently associated with suboptimal healthcare utilization among PWH. Our findings provide unique insight into the independent association of neighborhood of residence and healthcare utilization behavior among persons with HIV. While prior studies have associated neighborhood sociodemographics with individual markers of poor HIV outcomes [16–19], our study extends this association to patterns of engagement in HIV care. This study validates previous work from our group and sheds additional light on the intersection between adverse socioeconomic conditions and membership in a latent class characterized by suboptimal healthcare utilization.

More than half of people living with HIV are either undiagnosed, not in care, or inconsistently engaged in HIV care [20]. HIV care engagement is very important, primarily because effective ART improves health for PWH and decreases transmission. In addition, missed HIV clinic visits are independently associated with all-cause mortality among PWH and as a result the development of strategies to retain PWH in HIV care is a top priority among scientists and policymakers, as reiterated in the recent White House National HIV/AIDS Strategy [4, 21–23]. To date, most studies have looked at nonmodifiable patient-level determinants (race/ethnicity, age, sex), difficult-to-modify structural factors (housing status, educational achievement), or HIV-related care utilization (HIV clinic attendance, ART adherence) to determine persons most likely to disengage from care [5–9]. However, studies in large clinical cohorts have demonstrated the inadequacy of that approach. In the development of a predictive model of missed clinic visits among persons in HIV care, including >20 000 PWH in the Center for AIDS Research Network of Integrated Clinical Systems (CNICS) cohort, race did not rank among the top 20 most predictive variables among the determinants assessed for inclusion in the model [24]. Our presented work builds upon the direction presented in the CNICS study by taking a broader approach to characterizing subgroups of risk of HIV care disengagement. Our model, which includes ED utilization and hospital admission data, incorporates healthcare use not restricted to HIV care utilization alone to predict future engagement in HIV care. Prior healthcare utilization data are a useful and relatively easily obtainable metric for predicting future HIV care disengagement. Combining non-HIV-related and HIV-related healthcare use patterns with data on social determinants of health present a powerful tool for predicting future HIV care engagement outcomes.

Although prior reports from high-income countries have reported conflicting data on the association between socioeconomic status (SES) and HIV survival, none have used an aggregate indicator of SES to examine an association with the proximal intermediary to HIV survival, healthcare utilization, and HIV care engagement [16–19]. Of course, factors such as substance abuse and mental health diagnoses are more common in persons who reside in high-SDI neighborhoods, but our findings give unique insight on the direct link between where one lives, how they utilize care, and whether they persist in care, completely agnostic of static patient-level determinants like race, sex at birth, and ethnicity [25, 26]. Prior studies have suggested that neighborhood social factors (not just individual factors), even after controlling for other variables, are associated with adverse healthcare outcomes such as sexually transmitted infections [27]. This raises the intriguing possibility that health outcomes could be improved with nonspecific interventions aimed at improving socioeconomic conditions ("a rising tide lifts all boats").

The latent transition class analysis also provides important insights into the dynamics of healthcare utilization behavior over time among a clinical cohort of PWH. A few key patterns stand out in our analysis. Persons of low SES/high SDI, Black race, and female sex at birth were much less likely to transition from the nonadherent class in a given year to the adherent class the next year (Figure 1). These findings suggest a shortcoming in the HIV care infrastructure's ability to modify and optimize the use of healthcare among these key marginalized populations. Our inability to "move the needle" pertaining to healthcare use in these populations is troubling, likely associated with the inertia of sexism and structural racism's influence on healthcare delivery in the US [28–30]. Notably, transitions from the nonadherent to the adherent class were similar across the strata of age. Whether these disparities in healthcare use are due to suboptimal care access or differences of capability in navigating potentially complex healthcare systems across strata, these data suggest the need for interventions that consider the influence of structural bias on the health of women and people of color living with HIV.

This study has limitations. Patient hospitalization and ED visits outside of the Duke University Health System were not available to us, so patients who seek healthcare elsewhere may have been misclassified. In addition, persons who fell out of care but reestablished at another healthcare system during the same calendar year may have also been misclassified in this analysis. Further work will seek to use natural language processing–based algorithms to better refine the disengagement outcome variable, specifically differentiating "unanticipated disengagement from care" versus "anticipated departures from HIV care." Given the disproportionate number of persons who identify as Black/African American in our cohort compared to the demographics of PWH in other US regions, further research is needed to determine if they apply to different regions and populations across the country. In addition, there may be unmeasured variables associated with the complexities of socioeconomic status' association with health outcomes that were not captured in this analysis. Even though our study population is mostly urban, we acknowledge that for those patients in rural areas, the SDI measure might not appropriately capture social deprivation. Regarding the designation of latent classes, the derivation of the groupings did not take into consideration emerging drug resistance, and thus some persons who may be failing ART may be misclassified in the nonadherent latent class. There are 2 considerations: (1) Our model most likely classified persons with detectable viral loads who were otherwise engaged in care with few ED visits and admissions into the adherent class based on weighting of the individual indicator variables; (2) the outputs of the latent class model are probabilities of membership in each class, acknowledging that class membership is not deterministic. Nevertheless, future models will seek to incorporate the effect

of resistance mutation–driven virologic failure. Unfortunately, homeless persons were excluded from our analysis given our inability to ascertain SDI of residence. Future work will look into better ways to incorporate these persons into predictive models that are relevant to the experience of homeless persons with HIV. Finally, we acknowledge that health utilization–based risk stratification approaches for early identification of PWH at risk for suboptimal HIV care engagement might be harder to implement in standalone clinics not affiliated with inpatient or emergency care facilities, or medical facilities without EHR platforms.

In conclusion, our model robustly identified patients at high risk of care disengagement and poor clinical outcomes using data that are easily attainable from EHR platforms, making it potentially generalizable to HIV clinics in numerous settings. Our model provides an important first step on defining risk profiles that go beyond measuring the impact of racism on health outcomes, and determines future health utilization and engagement by past behavior. Our findings provide foundational data for tools that potentially could be used to quantify and stratify the risk of HIV care engagement regardless of locale and independent of the racial and ethnic makeup of the target population. Validation of our model in other settings will be an important step in designing interventions focused on improving outcomes among PWH.

Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

Patient consent. Given the retrospective nature of this work, the Duke University Institutional Review Board (IRB) approved a waiver of consent for the conduct of this study. The design of the work has been approved by the Duke IRB and conforms to standards currently applied in the United States.

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Potential conflicts of interest. N. L. O. has received consulting fees from Gilead Sciences. All other authors report no potential conflicts.

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