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ORIGINAL PAPER

Long-Term Supportive Housing is Associated with Decreased Risk for New HIV Diagnoses Among a Large Cohort of Homeless Persons in New York City

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Abstract
It is unknown whether providing housing to persons experiencing homelessness decreases HIV risk. Housing, including access to preventive services and counseling, might provide a period of transition for persons with HIV risk factors. We assessed whether the new HIV diagnosis rate was associated with duration of supportive housing. We linked data from a cohort of 21,689 persons without a previous HIV diagnosis who applied to a supportive housing program in New York City (NYC) during 2007–2013 to the NYC HIV surveillance registry. We used time-dependent Cox modeling to compare new HIV diagnoses among recipients of supportive housing (defined a priori, for program evaluation purposes, as persons who spent > 7 days in supportive housing; n = 6447) and unplaced applicants (remainder of cohort), after balancing the groups on baseline characteristics with propensity score weights. Compared with unplaced applicants, persons who received ≥ 3 continuous years of supportive housing had decreased risk for new HIV diagnosis (HR 0.10; CI 0.01–0.99). Risk of new HIV diagnosis decreased with longer duration placement in supportive housing. Supportive housing might aid in primary HIV prevention.

Keywords HIV prevention · Housing · Propensity score analysis · Survival analysis · Marginal structural models

Introduction

Persons who are homeless or lack a stable living environment have an increased risk for human immunodeficiency virus (HIV) infection [1, 2]. The rate of new HIV diagnoses among residents of New York City (NYC) homeless family shelters is > 2 times the rate of new HIV diagnoses than the general population [3]. In part, this might be attributable to a higher prevalence of practices associated with increased exposure to HIV among homeless or unstably housed persons; drug use, needle sharing, and sex exchange have been reported to be more common among persons without stable housing than among the general population [4–6]. A study of HIV-negative homeless persons entering supportive housing found that few participants had received HIV prevention education in the past year (46%) and < 1% received prescriptions for pre-exposure prophylaxis [7]. Providing housing to persons experiencing homelessness might address structural drivers of HIV infection, which can include both indirect and direct causes and consequences of homelessness (e.g., poverty, marginalization, and experiences of sexual violence), which either limit a person's ability to prevent infection or increase their risk of exposure to the virus [8]. Structural drivers for HIV infection risk among persons experiencing homelessness might include the chronic stress of daily survival, neighborhood effects, reduced access to services, substance use as self-medication, and exchanging drugs or sex to meet basic needs including a place to stay [9].

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Housing for persons living with HIV (PLHIV) is associated with a decrease in risk factors for forward HIV transmission. PLHIV whose housing status improved reduced their risk by half for needle use, needle sharing, and condomless sex, compared with persons without housing status change [9]. Housing assistance to PLHIV increased access to HIV primary care, retention in care, and appropriate treatment [10], which decreases HIV transmission risk [11]. In a randomized trial conducted during 2003–2006, providing supportive housing to PLHIV significantly improved survival with intact immunity (CD4 cell count ≥ 200) and viral load (VL) suppression (VL < 100,000) [12]. However, whether providing supportive housing to persons who are homeless is effective for primary prevention of HIV infection is unknown.

NYC has the largest number of persons experiencing homelessness of any U.S. city (14% of all persons experiencing homelessness nationwide in 2015) [13]. We sought to determine whether providing supportive housing to persons who were homeless or at risk for homelessness in NYC decreased rates of new HIV diagnosis. We tested two hypotheses, including that new HIV diagnosis incidence is lower among those who were placed in a supportive housing program than among unplaced program applicants (i.e., 'intention-to-treat'); and that stable, long-term residence in supportive housing is associated with decreased incidence of new HIV diagnosis.

Methods

Study Design and Population

We retrospectively studied a cohort of persons who applied to and were eligible for a permanent supportive housing intervention in NYC during 2007–2013. The supportive housing program provided housing and supportive services, including case management and harm reduction services, to > 7000 persons experiencing homelessness or at-risk for homelessness beginning in 2007. Persons were determined by the NYC Human Resources Administration to be eligible for the program if they met the following conditions: homeless with serious mental health diagnoses (SMH) or mental health diagnoses and a substance use disorder (SUD); discharged from state-operated psychiatric facilities and at risk for homelessness; homeless with SUD or treated for an SUD; heads of families with SMH, SUD and mental illness, or disabling medical condition; or young adults leaving foster care and at risk for homelessness [14]. Eligible applicants were then selected for housing placement by local housing agencies. Details about this program have been published elsewhere [15] (program details can be found at: http://shnny.org/budget-policy/nyc/ny-ny/ny-ny-iii).

Persons were included in the evaluation ("evaluation cohort", n = 21,689) if at the time of program eligibility they were aged ≥ 18 years (n = 24,537), and had not received a previous diagnosis of HIV or previously received HIV supportive housing services (n = 2848 excluded for these reasons). The evaluation cohort was followed from the date of first eligibility for the housing program until the earlier of new HIV diagnosis date or censor date. Censoring occurred at the earlier of death or December 31, 2013.

Data Sources

The NYC Department of Health and Mental Hygiene (DOHMH) informatics division matched records of applicants to administrative datasets using name, date of birth, sex, and social security number. Data from New York State (NYS) psychiatric facilities, Medicaid, cash assistance, food stamps, and NYC subsidized housing programs were matched deterministically. Data from NYC jails, NYC adult and family homeless shelters, NYC DOHMH vital records and NYC DOHMH HIV surveillance registries were matched probabilistically (QualityStage®, IBM Corporation, Armonk, New York). The new HIV diagnosis outcome was ascertained from the NYC DOHMH HIV surveillance registry through December 31 2013, by using date of first diagnosis of HIV in NYC, in accordance with the CDC surveillance case definition [16]. De-identified, matched data were stored in a DOHMH secure server.

We used provider (clinicians, social workers, or case managers) diagnoses and supporting documentation provided by the referring agency at the time of application to ascertain history of mental health diagnoses (mood disorders, personality disorders, and psychotic disorders), current and past substance use patterns (alcohol, amphetamines, cocaine, and opiates), current enrollment in a substance use treatment program, highest attained education (high school diploma or greater versus less than high school diploma), and self-reported race/ethnicity. HIV screening was not required for inclusion in the evaluation.

Intervention Group Assignment and Inverse Probability of Treatment Weighting

Evaluation cohort members who received > 7 days of supportive housing constituted the intervention group and those who were not placed into housing or placed ≤ 7 days constituted the comparison group [14]. The 7-day cutoff was selected a priori after discussions with program staff members, as persons should receive supportive services after 7 days of housing placement. Because evaluation cohort members were not randomly assigned to housing placement, we constructed a logistic regression model to predict the likelihood of receiving the intervention (i.e., propensity

score) by using the same baseline variables used for program evaluation described elsewhere [15]. The inverse probability of treatment (IPT) weight was calculated as the inverse of the propensity score for those receiving the intervention and the inverse of 1 minus the propensity score for those who did not receive the intervention. To minimize influences from large weights, we stabilized the IPT weights (SIPTW) by multiplying the weights by the marginal probability of housing placement [17].

Statistical Analyses

We used Stata® v14.0 (StataCorp, LLC, College Station, Texas) for all statistical analyses. Two-sided *P* values <0.05 were considered statistically significant. We compared baseline characteristics of intervention and comparison groups by calculating standardized differences (difference in sample means among the intervention and comparison groups divided by the square root of the average of sample variances) and two-sided *P* values for corresponding F-statistics before and after applying SIPTW. Person-time was calculated from the date of first eligibility for each applicant until the time of the outcome (new HIV diagnosis) or censoring. Housing placement was coded as a binary variable (unplaced versus placed in housing intervention); persons entered the cohort unplaced and were recoded as placed in housing on the date that they first moved into supportive housing.

We compared crude incidence rates for new HIV diagnosis between the intervention and comparison groups by using the number of new HIV diagnoses as the numerator and the total number of person-years as the denominator and calculated 95% confidence intervals (95% CIs) by using jackknife standard errors.

To calculate hazard ratios (HRs) we first used an intention-to-treat approach, despite the design being observational, in order to generate conservative estimates of the marginal effect of housing placement. Persons among the intervention group were coded as placed in housing from the date of first placement until they were censored or met the new HIV diagnosis outcome, regardless of their housing pattern after their initial assignment to the intervention. We used Cox proportional hazards regression to calculate HRs for new HIV diagnosis, comparing intervention and comparison group in the SIPTW sample by using the time-varying housing variable.

To assess possible new diagnosis bias between the intervention and comparison groups, we compared acute HIV infection cases as identified by the HIV surveillance program based on either provider diagnosis or a pattern of laboratory results consistent with diagnosis of HIV infection in the acute stage [18]. Since 2004, NYC jails have offered rapid HIV testing during medical assessment at intake [19]. Therefore, persons with a history of incarceration are likely to be screened for HIV more frequently than persons without that history. To account for possible increased HIV detection among applicants who were incarcerated after cohort entry, we created a marginal structural model including incarceration history and SIPTW specific for each time *t* (in years) [20]. We used doubly robust pooled logistic regression to measure a pooled odds ratio (OR), comparing new HIV diagnoses in the intervention and comparison groups, adjusted for incarceration history [21].

To test whether longer duration of stable housing was associated with a decreased risk for new HIV diagnosis, we conducted a time-dependent analysis by using the cumulative duration of the first period spent in supportive housing that occurred after placement for evaluation cohort members among the intervention group. We defined the duration of the initial continuous housing placement as the number of years in supportive housing without an interruption of ≥ 30 days, because interruptions of <30 days often represented moving from one permanent supportive housing unit to another unit. We estimated HRs for each additional year of housing placement (placement × cumulative years placed), relative to the comparison group, by using a time-dependent Cox proportional hazards model in which the exposure status changed when a person was first placed, or with each year after placement during the continuous placement period.

Results

Participants

A total of 21,689 persons met eligibility criteria for the evaluation cohort, and these persons contributed 72,541 person-years (mean observation time 3.3 years). The majority of evaluation cohort members were male (69.0%) and non-Hispanic Black (53.9%) (Table 1). Among evaluation cohort members, 6447 (29.7%) received >7 days of housing placement and were considered the intervention group. Before propensity score weighting, the intervention group had a higher proportion of non-Hispanic Black persons (55.7 vs. 53.1%, $P < 0.001$), persons with current alcohol (13.9 vs. 8.6%, $P <0.001$), cocaine (3.7 vs. 2.1%, $P < 0.001$), or opiate (1.9 vs. 1.2%, $P < 0.001$) use, persons who received Medicaid (83.5 vs. 73.9%, $P < 0.001$) or food stamps (60.3 vs. 47.9%, $P < 0.001$), and persons who had spent time in single shelters (48.1 vs. 40.7%, $P < 0.001$). A lower proportion of persons in the intervention group had less than a high school diploma (42.8 vs. 46.0%, $P < 0.001$) or history of psychotic (28.2 vs. 42.9%, $P < 0.001$) and personality disorders (11.5 vs. 14.7%, $P < 0.001$) than the comparison group. After propensity score weighting, no significant differences between intervention and comparison groups were noted. Intervention group applicants were placed in

Table 1 Baseline characteristics of evaluation cohort members—New York City, 2007–2013

	Frequency (n [%])			Standardized difference[a]	
	Total sample (no. 21,689)	Comparison group (no. 15,242)[b]	Intervention group (no. 6447)[c]	Unweighted sample	Weighted sample
Demographics					
Age at eligibility (years)					
18–24	3064 (14.1)	2231 (14.6)	833 (12.9)	0.05**	0.02
25–34	3143 (14.5)	2294 (15.1)	849 (13.2)	0.05***	0.02
35–44	4341 (20.0)	3061 (20.1)	1280 (19.9)	0.01	0
45–54	6979 (32.2)	4765 (31.3)	2214 (34.3)	0.07***	0.01
55–64	3486 (16.1)	2405 (15.8)	1081 (16.8)	0.03	0.01
≥65	676 (3.1)	486 (3.2)	190 (2.9)	0.01	0.02
Sex					
Male	14,972 (69.0)	10,485 (68.8)	4487 (69.6)	0.02	0.01
Race					
Non-hispanic white	3154 (14.5)	2340 (15.4)	814 (12.6)	0.08***	0.01
Non-hispanic black	11,681 (53.9)	8088 (53.1)	3593 (55.7)	0.05***	0
Hispanic	6086 (28.1)	4229 (27.7)	1857 (28.8)	0.02	0
Asian	242 (1.1)	199 (1.3)	43 (0.7)	0.07***	0.01
Other	526 (2.4)	386 (2.5)	140 (2.2)	0.02	0.01
Education					
Less than high school diploma	9770 (45.0)	7009 (46.0)	2761 (42.8)	0.06***	0
U.S. citizen	20,450 (94.3)	14,360 (94.2)	6090 (94.5)	0.01	0.01
Veteran status	1326 (6.1)	914 (6.0)	412 (6.4)	0.02	0
History of substance abuse[d]					
Current substance abuse					
Alcohol	2204 (10.2)	1309 (8.6)	895 (13.9)	0.17***	0.01
Amphetamines	11 (0.1)	8 (0.1)	3 (0.05)	0	0
Cocaine	555 (2.6)	316 (2.1)	239 (3.7)	0.1***	0
Opiates	313 (1.4)	189 (1.2)	124 (1.9)	0.06***	0
Currently in a treatment program	7108 (32.8)	4673 (30.7)	2435 (37.8)	0.15***	0.01
Past history of substance abuse	16,648 (76.8)	11,447 (75.1)	5201 (80.7)	0.14***	0
History of mental health diagnoses[e]					
Mood disorder	8870 (40.9)	6260 (41.1)	2610 (40.5)	0.01	0.01
Personality disorder	2986 (13.8)	2245 (14.7)	741 (11.5)	0.10***	0
Psychotic disorder or schizophrenia	8355 (38.5)	6538 (42.9)	1817 (28.2)	0.3***	0.02
History of housing and incarceration (2 years before eligibility)					
Any days spent in single shelter	9297 (42.9)	6197 (40.7)	3100 (48.1)	0.15***	0.01
Any days spent in family shelter	1852 (8.5)	1271 (8.3)	581 (9.0)	0.02	0
Any days spent incarcerated	3022 (13.9)	2083 (13.7)	939 (14.6)	0.01	0
Benefits received					
Social security	1815 (8.4)	1321 (8.7)	494 (7.7)	0.04*	0
Medicaid	16,647 (76.8)	11,261 (73.9)	5386 (83.5)	0.24***	0.01
Medicare	1959 (9.0)	1410 (9.3)	549 (8.5)	0.03	0
Supplementary security income or disability	7083 (32.7)	5116 (33.6)	1967 (30.5)	0.07***	0.01
Food stamps	11,186 (51.6)	7297 (47.9)	3889 (60.3)	0.25***	0.01

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

[a]Standardized difference is the difference in sample means in the treatment and comparison subsamples as a proportion of the square root of the average of the sample variances in the treatment and comparison groups

[b]Received ≤7 days placement in the permanent supportive housing intervention

[c]Received >7 days placement in the permanent supportive housing intervention

[d]Reported by participant to provider

[e]Diagnosed by provider

supportive housing, on average, a total of 2.3 years (range 8 days–9.9 years).

Intention-to-Treat Analysis of New HIV Diagnoses

During the evaluation period, 74 new HIV diagnoses (n = 22 intervention group and n = 52 comparison group) were identified. The crude new HIV diagnosis rate among the intervention group (9.03/10,000 person-years; 95% CI 5.61, 14.52) was lower than the incidence rate among the comparison group (10.62/10,000 person-years; 95% CI 8.19, 13.77), but this difference was not statistically significant. After propensity score weighting, risk for new HIV diagnosis was non-significantly lower among the intervention group then among the comparison group in the intention-to-treat analysis (HR 0.80; 95% CI 0.45, 1.42) (Table 2).

Assessment of Potential HIV Detection Bias

After cohort entry, proportion of persons incarcerated (12.9% among intervention group versus 13.2% among comparison group, $P = 0.59$) and the number of episodes of incarceration (mean 2.6 among intervention group versus 2.8 among comparison group, $P = 0.06$) were not significantly different between groups; however, the comparison group spent significantly more days incarcerated during the evaluation period than the intervention group (mean 34.0 days among comparison group versus 24.6 days among intervention group, $P < 0.001$). In the marginal structural model accounting for time incarcerated, the intention-to-treat pooled odds ratio for new HIV diagnosis was 0.77 (95% CI 0.33, 1.76) among intervention versus comparison group. The percentages of persons newly diagnosed with acute HIV infection among intervention (13.0%) and comparison (14.0%) groups were not significantly different (χ^2 $P = 0.9$) indicating no bias in the earlier diagnosis of HIV among the intervention group.

Association Between Duration of Supportive Housing Residence and New HIV Diagnoses

HR for new HIV diagnosis decreased for those in the intervention group as the duration of housing placement increased (Table 3). For each additional year of placement in

Table 2 Intention-to-treat analysis of risk of new HIV diagnosis among intervention[a] versus comparison[b] groups in evaluation cohort for a supportive housing intervention—New York City, 2007–2013

Model	Measure of association	95% CI
Stabilized inverse probability of treatment weight Cox proportional hazards model[c]	Hazard ratio 0.80	0.45, 1.42
Stabilized inverse probability of treatment weights and time-varying incarcerations marginal structural model[d]	Pooled odds ratio 0.77	0.33, 1.76

[a]Received > 7 days placement in the permanent supportive housing intervention

[b]Received ≤ 7 days placement in the permanent supportive housing intervention

[c]Inverse probability of treatment weights created by using a logistic regression model of baseline values of covariates presented in Table 1

[d]Inverse probability of treatment weights created by using a logistic regression model of baseline values of covariates presented in Table 1 and change annually or with the beginning or ending of an episode of incarceration

Table 3 Time-dependent hazard ratios for years of continuous housing placement among intervention[a] versus comparison[b] groups in evaluation cohort for a supportive housing intervention—New York City, 2007–2013

	Hazard ratio	95% CI
Stabilized inverse probability of treatment weight model[c]		
Placement for 1 year versus comparison group[d]	0.98	0.55–1.76
Placement for 2 years versus comparison group[d]	0.31	0.09–1.14
Placement for 3 years versus comparison group[d]	0.10	0.01–0.99
Each subsequent year of placement versus previous year[e]	0.32	0.11–0.92

[a]Received > 7 days of placement in the permanent supportive housing intervention

[b]Received ≤ 7 days of placement in the permanent supportive housing intervention

[c]Inverse probability of treatment weights created using a logistic regression model of baseline values of covariates presented in Table 1, with exposure variable (housing placement) among the intervention group varying over time, beginning with the date of first housing placement and ending on the date of move out preceding an interruption of ≥ 30 days, after which the value of the interaction term did not vary

[d]Hazard ratio is the exponentiated sum of coefficients for housing placement and the interaction term (placement × cumulative years placed)

[e]Hazard ratio is the exponentiated coefficient of the interaction term

the housing program, a significant reduction in risk for new HIV diagnosis among those who received housing placement (HR 0.32; 95% CI 0.11, 0.92) was found. Those who were continuously placed for three years had a significant reduction in the risk for new HIV diagnosis, compared with those in the comparison group (HR 0.10; 95% CI 0.01, 0.99).

Discussion

Among this evaluation cohort of applicants to a supportive housing program in NYC, risk for new HIV diagnosis significantly decreased with longer duration of continuous housing placement. These findings underscore the importance of long-term stable housing to reduce HIV risk among persons who are homeless.

Despite an approximately 20% decrease in the risk for new HIV diagnosis in the intention-to-treat analysis, heterogeneity in the duration of housing placement among persons placed in housing could have been responsible for the failure to detect a significant reduction in new HIV diagnoses. Certain persons in the intervention group were housed for as few as 8 days.

Previous research regarding housing as an intervention to decrease substance use and mental health morbidity provides evidence that provision of stable housing can improve health outcomes [22–25]. Interventions to reduce the risk for HIV infection by modifying social, economic, political, and environmental factors associated with HIV risk, including maintenance of a stable housing environment [8], can decrease HIV risk through multiple pathways. Stable housing might decrease exposure to neighborhood stressors associated with daily survival, or reduce the need to exchange sex or drugs to meet basic daily needs, including food, money, or a place to reside [9]. Although persons who are homeless are known to have a higher prevalence of behaviors associated with HIV transmission [5, 26, 27], published studies have not previously demonstrated that housing decreases their risk for new HIV diagnosis.

We report that permanent supportive housing significantly reduced HIV diagnosis risk in a time-dependent manner, indicating that long-term housing placement is needed for HIV prevention. The idea that stable housing can decrease risk of sexually-transmitted infections is also supported by a study of young adults aging out of foster care in New York City. In that study, young adults who received supportive housing placement were found to be significantly more likely to experience housing stability and to have decreased incidence of sexually transmitted infections other than HIV [28]. Sustained provision of supportive services, including case management and referral to substance use and legal services, might also have contributed to the decrease in HIV diagnosis rate we observed.

This evaluation has at least three major limitations. Persons were not randomly assigned to the intervention. We used propensity score methods to reduce confounding attributable to nonrandom assignment to the intervention. Although propensity score methods eliminated observed baseline differences between the intervention and comparison groups, residual confounding attributable to unmeasured factors (e.g., needle sharing or condomless sex) that might be related to HIV risk and testing behaviors or housing receipt or maintenance might exist. Second, even assuming perfect matching of new HIV diagnosis cases, true HIV incidence is unknown among the cohort because we used the date of new diagnosis in the NYC HIV registry as a proxy for HIV incidence. New diagnoses do not account for all incident infections [29]; however, an estimated 93% of HIV-infected New Yorkers have been diagnosed and reported to the HIV registry in NYS [30] and NYC [31]. We accounted for potential biases in ascertaining new HIV diagnoses in the following two ways: we created a marginal structural model, including incarcerations because HIV testing is known to occur at NYC jails, and we compared the proportion of acute HIV infections among intervention and comparison groups. Neither of these analyses indicate that ascertainment of HIV diagnoses differed between intervention and comparison groups. Last, although lesbian, gay, bisexual, and transgender (LGBT) persons are over-represented in homeless populations [32] and might have decreased awareness or utilization of HIV preventive services including pre-exposure prophylaxis [33], we did not have data on sexual orientation or gender identity to include in the evaluation.

Because of the large sample size needed to investigate the relatively rare outcome of HIV infection, no randomized controlled trials have been conducted studying the influence of housing programs on HIV incidence. We analyzed observational data from a large cohort of persons experiencing and at risk for homelessness to identify new HIV diagnoses among those who received placement in a supportive housing program, balancing on baseline factors. Matching administrative records and HIV registry data enabled us to identify new HIV diagnoses in the absence of follow-up of individual participants.

Our finding that continuous housing placement decreases the risk for incident HIV diagnosis provides new evidence for supportive housing as primary prevention for HIV and extends the research concerning the association between unstable housing and HIV. City, state, and federal efforts to provide persons who are homeless with permanent housing and supportive services might, in addition to reducing HIV risk behaviors, decrease new HIV infections and reduce costs associated with managing HIV disease in those patients.

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Compliance with Ethical Standards

Conflict of interest The authors report no conflicts of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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