

# The Impact of Supportive Housing on Liver-Related Outcomes Among Persons With Hepatitis C Virus Infection

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**Background.** Hepatitis C virus (HCV) infection disproportionately impacts people experiencing homelessness. Hepatitis C virus can lead to negative health outcomes, including mortality. We evaluated the impact of a permanent supportive housing (PSH) program (ie, “treatment”) on liver-related morbidity and mortality among persons with chronic homelessness and HCV infection.

**Methods.** We matched records for persons eligible for a New York City PSH program (2007–2014) with Health Department HCV and Vital Statistics registries and Medicaid claims. Among persons diagnosed with HCV before or 2 years posteligibility, we added stabilized inverse probability of treatment weights to negative binomial regression models to compare rates for liver disease-related emergency department visits and hospitalizations, and hazard ratios for mortality, by program placement 2 and 5 years posteligibility.

**Results.** We identified 1158 of 8783 placed and 1952 of 19 019 unplaced persons with laboratory-confirmed HCV infection. Permanent supportive housing placement was associated with significantly reduced liver-related emergency department visits (adjusted rate ratio [aRR] = 0.76, 95% confidence interval [CI] = .61–.95), hospitalizations (aRR = 0.62, 95% CI = .54–.71), and all-cause (adjusted hazard ratio [aHR] = 0.65, 95% CI = .46–.92) and liver-related mortality (aHR = 0.72, 95% CI = .09–.83) within 2 years. The reduction remained significant for hospitalizations after 5 years.

**Conclusions.** Placement into PSH was associated with reduced liver-related morbidity and mortality among persons with HCV infection and chronic homelessness.

**Keywords.** hepatitis C virus; homelessness; housing; Medicaid; supportive housing.

The prevalence of hepatitis C virus (HCV) infection in New York City adults is estimated to be 1.8% (1.5%–2.0%) [1]. The sequelae of HCV infections can include liver disease, liver cancer, and premature mortality [2, 3]. Before the introduction of direct-acting antivirals (DAAs), first approved in 2011 and covered by state Medicaid programs beginning in 2014 [4], treatment options for HCV were less efficacious and were accompanied by harsh side effects [2].

The HCV epidemic disproportionately impacts persons with human immunodeficiency virus (PWH), those born during 1945–1965 (“baby boomers”), persons with a history of injection drug use, and those who have been incarcerated [5–7]. All 4 of these populations are also more likely to be affected

by homelessness [8, 9], and homelessness and unstable housing are associated with HCV infection [10–12]. One systematic review calculated a random-effects pooled prevalence estimate of 20.3% (95% confidence interval [CI] = 15.5–25.2) for HCV infection among populations experiencing homelessness [13], which is much higher than the estimated 1% prevalence among the general adult population [14]. Hepatitis C virus infection may also be an important predictor for emergency department (ED) use among persons experiencing homelessness [15].

Permanent supportive housing is an intervention that provides both housing and supportive services to persons with complex medical histories who are chronically homeless or at risk of homelessness. It has been shown to not only improve housing stability [16] but also to improve health outcomes and reduce the utilization of shelters and ED visits and the frequency of incarceration [17–22]. Placement into supportive housing has been previously associated with reduced transmission of certain infectious diseases, including human immunodeficiency virus (HIV) [23] and sexually transmitted infections [24], as well as a reduced risk of progression to acquired immune deficiency syndrome (AIDS) among PWH [25]. There are few studies examining HCV among persons in supportive housing [6] and none to our knowledge examining the impact of supportive housing on HCV morbidity and mortality.

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In this study, we sought to describe the prevalence of HCV among a population that was eligible for a New York City (NYC) permanent supportive housing program. We then evaluated whether placement into supportive housing was associated with a reduction in liver-related ED visits, hospitalizations, and deaths among persons with HCV infection.

## METHODS

### Program and Study Population

New York/New York III (NUNYIII), a partnership between NYC and New York State (NYS), is a large-scale supportive housing program based in NYC, whose goal is to establish 9000 supportive housing units [20]. The NUNYIII provides subsidized, permanent housing along with supportive social services and connections to healthcare. The program began housing persons in 2007, and its target populations include chronically homeless persons or families where the head of household has a serious mental illness (SMI) or a substance use disorder (SUD) and mental illness, PWH who also have SMI or SUD and mental illness, persons with an active or treated SUD, and young adults who have aged out of foster care and are at risk of becoming homeless. For NUNYIII, a person experiencing chronic homelessness is one with a history of living on the streets or in a shelter for 2 of the past 4 years, or for someone living with a disability, 12 of the past 24 months.

After a person is determined to be eligible, upon unit availability, they are interviewed by the housing program provider, who are then required to select 1 of every 3 persons referred to them. Therefore, placement into NUNYIII is not randomly assigned. We defined “placed” persons as those who were housed in a NUNYIII unit for 8 or more days. “Unplaced” persons were those who were eligible for NUNYIII housing but either not placed into a unit within the program or placed for 7 or less days, and they were also not placed into another supportive housing program within 6 months of their NUNYIII eligibility date. The 7-day cut-off has previously been determined to provide the minimum benefit of supportive housing placement [20]. A more in-depth description of the NUNYIII supportive housing program and its evaluation have previously been described [20, 26].

All persons who were eligible for NUNYIII consented to having their data shared for evaluation purposes. The NYC Department of Health and Mental Hygiene (DOHMH) Institutional Review Board determined this study to be program evaluation and not human subjects research and therefore not under its purview.

### Data Sources

We identified HCV cases among people eligible for NUNYIII via match to DOHMH’s HCV surveillance registry. Laboratories are required to send all positive HCV test results (ribonucleic acid [RNA] and antibody), negative RNA results, and genotype

results for NYC residents to the DOHMH via an electronic reporting system. Laboratory reports are automatically deduplicated, and partial matches are manually reviewed. A more in-depth description has been previously published [27].

In addition, we matched the NUNYIII eligible cohort to multiple administrative datasets, including those from the NYC Department of Social Services for NUNYIII programmatic data, which includes the 2010e supportive housing application data and shelter use, the NYC Department of Corrections for incarceration, the NYC DOHMH registries for deaths and HIV diagnosis status, the NYS Department of Health for Medicaid claims, and the NYS Office of Mental Health for psychiatric facility stays. We obtained all data related to HIV diagnosis from the 2010e application and the NYC DOHMH HIV registry, and data on HIV transmission risk factors were provided by the HIV registry. Data for Medicaid claims, shelter use, incarceration, and information included in the 2010e covered the period 2 years before eligibility, whereas HCV and HIV diagnoses included diagnoses at any time before eligibility, and all data matches were limited to 5 years posteligibility date. A prior human review of a random sample of cases found acceptable levels of sensitivity (93%) and specificity (96%) for the matching performance [24].

### Case Definition

We limited our analysis to persons with an HCV infection who first became eligible for NUNYIII during 2007–2014 (N = 3110). A person with an HCV infection was defined as someone with a positive RNA test for HCV at any time before or 2 years after their first date of NUNYIII eligibility. Individuals with only a positive antibody test and no positive RNA test in this same period were removed from the analysis (n = 516).

### Liver-Related Health Outcomes

We used Medicaid data to identify liver-related ED visits and hospitalizations, requiring either a liver-related principal or secondary diagnosis (*International Classification of Diseases, Ninth Revision* [ICD-9] or ICD-10) or a Current Procedural Terminology (CPT) code. Potential diagnoses included those associated with chronic liver disease and its sequelae, chronic or acute HCV, and liver cancer, with a subset used to indicate end-stage liver disease (ESLD) (see [Supplementary Table 1](#)) [28–30].

### Statistical Analysis

First, we described this population at baseline (ie, as of their NUNYIII eligibility date) stratified by NUNYIII placement status (placed vs unplaced). We then analyzed all persons for outcomes within 2 years of program eligibility, although only persons who became eligible for NUNYIII 2007–2012 were included in our subcohort for analysis of 5-year outcomes. We described mortality and leading causes of death between those

placed and unplaced 2 and 5 years posteligibility and stratified by whether the death was premature (ie, before age 65).

Next, we examined liver-related health events and deaths 2 and 5 years posteligibility. Because placement into housing was not random, we used inverse probability of treatment weighting (IPTW) to adjust for inherent differences in characteristics between the 2 groups. First, we used a multivariable logistic regression model to calculate a propensity score for an individual's probability of having been assigned to the treatment group (ie, having been placed into NYNYIII supportive housing). Covariates used in our model were characteristics associated with placement status based on a previous analysis [20] and included baseline demographic, physical and mental health (including HIV status and a diagnosis of a serious mental illness), and behavioral characteristics (including substance use history), as well as receipt of public benefits and prior shelter stays, jail events, and Medicaid utilization (Supplementary Table 2). Next, we calculated the IPTW, which is the inverse probability of having been assigned to the treatment group to which they were assigned. We then derived a stabilized IPTW by multiplying the IPTW by the marginal probability of treatment (ie, the proportion of eligible persons who were placed into NYNYIII supportive housing.) Finally, we calculated standardized differences to ensure that balance in the baseline covariates was achieved by comparing their distribution before and after stabilized IPTW [31]. Along with stabilized IPTW, all outcome regression models included all the covariates used in the initial propensity score model to control for residual confounding [32].

We compared the number of liver-related and ESLD ED visits and hospitalizations between placed and unplaced groups using negative binomial regression models to account for overdispersion with generalized estimating equations and stabilized IPTW, using the log of the number of days that a person was enrolled in Medicaid as an offset term. We then examined time to first ESLD event only among those without a previous ESLD event in the 2 years before program eligibility. For this subgroup, we calculated adjusted hazard ratios (aHRs) using Cox proportional hazards models. We also calculated hazard ratios for all-cause mortality. To address potential bias due to informative censoring, when analyzing liver-related and ESLD deaths specifically, we calculated cause-specific hazards using competing risks models in which the competing risk was a nonliver-related death.

We conducted a sensitivity analysis in which we examined outcomes from 2007 through the end of 2013 to analyze the effect of supportive housing on liver-related outcomes before the introduction of DAAs as recommended treatment for HCV infection. Finally, we conducted a second sensitivity analysis in which we examined 2-year outcomes only among our 5-year cohort, to observe whether there were differences in persons who had 5 years of follow-up time versus those with only 2 years of follow-up time.

To assess whether a potential explanation for any differences in liver-related morbidity and mortality could be due to differential receipt of medical evaluation and management outpatient health services, we compared the proportion of persons who had at least 1 of these visits 2 and 5 years posteligibility by placement status and calculated adjusted risk ratios. An evaluation and management outpatient visit was one that included one of the following procedure codes: 99201–99205, 99211–99215, or 99241–99245 [33]. All analyses were conducted using SAS Enterprise Guide version 7.1 (SAS Institute, Cary, NC) and statistical significance was a  $P < .05$ .

## RESULTS

We identified 1158 of 8783 (13.2%) placed and 1951 of 19019 (10.3%) unplaced persons who had a laboratory-confirmed HCV infection at or within 2 years post-NYNYIII program eligibility ( $P < .0001$ ). Eighty-four percent of persons were diagnosed before eligibility, and the difference in this proportion between placed and unplaced was not statistically significant ( $P = .53$ ). More than three quarters of these persons were male and 45 years or older at eligibility, and the majority was Black/African American or Latino/Hispanic (Table 1). Baby boomers, that is, those born between 1945 and 1965, comprised 77% (placed) and 70% (unplaced) of infected persons ( $P < .001$ ). The proportion of persons with comorbid HIV/AIDS was 34% among placed and 22% among unplaced persons ( $P < .001$ ), with the most frequent HIV transmission risk category for both groups being persons who used injection drugs (69% placed and 70% unplaced,  $P = .02$ ). Eighty percent of placed persons and 76% of unplaced persons had an SUD ( $P < .001$ ), and approximately 60% of all persons with HCV had a history of opioid use. Approximately one quarter of persons with HCV had at least 1 incarceration event within 2 years of program eligibility. These characteristics were well balanced between the placed and unplaced groups after weighting via stabilized IPTW (Supplementary Table 2). For those with 5 years of follow-up time, the median length of stay in NYNYIII was 1446 days (interquartile range [IQR] = 544–1826), and for the entire analytic sample, the median stay was 1144 days (IQR = 576–1826).

Among persons with HCV infection, we observed that 4% (placed) and 6% (unplaced) had died within 2 years of program eligibility and 14% (placed) and 12% (unplaced) had died within 5 years, the large majority of whom were <65 years (Table 2). The leading causes of death for both groups were drug use and accidental poisoning, HIV, and malignant neoplasms.

We observed significantly reduced adjusted rate ratios (aRRs) for those placed into housing compared with those who were unplaced for liver ED visits (aRR = 0.76, 95% CI = .61–.95), liver hospitalizations (aRR = 0.62, 95% CI = .54–.71), and ESLD hospitalizations (aRR = 0.31, 95% CI = .20–.49) for

**Table 1. Baseline Characteristics of Persons With Hepatitis C Virus Infection Before or Within 2 Years of Eligibility by Placement Into New York/New York III Supportive Housing, 2007–2014**

Characteristics	Placed N (%)	Unplaced N (%)	$\chi^2$ P value
Total	1158 (37.2)	1951 (62.8)	...
Gender	...	...	.20
Male	931 (80.4)	1531 (78.5)	...
Female	227 (19.6)	420 (21.5)	...
Age at Eligibility	...	...	.023
18–44	235 (20.3)	473 (24.2)	...
45–64	892 (77.0)	1416 (72.6)	...
65+	31 (2.7)	62 (3.2)	...
Race and Ethnicity	...	...	.24
Black or African American	532 (45.9)	822 (42.1)	...
Latino or Hispanic	429 (37.1)	760 (39.0)	...
White	175 (15.1)	323 (16.6)	...
Asian, Pacific Islander, Native American, and other	22 (1.9)	46 (2.4)	...
Education	...	...	.66
Less than high school diploma	512 (44.2)	883 (45.3)	...
High school diploma or greater	612 (52.9)	1003 (51.4)	...
Other	34 (2.9)	65 (3.3)	...
Baby Boomer (born 1945–1965)	888 (76.7)	1368 (70.1)	.0004
Median Medicaid eligible <sup>a</sup> days—2-year follow up (IQR)	673 (481–728)	530 (257–721)	<.0001
Median Medicaid eligible <sup>a</sup> days—5-year follow up (IQR)	1518.5 (940–1805)	1115 (476–1704)	<.0001
HIV positive	396 (34.2)	426 (21.8)	<.0001
HIV transmission risk category (among those HIV positive)	...	...	.02
Intravenous drug user	262 (66.2)	297 (69.7)	...
Men who have sex with men	41 (10.4)	27 (6.3)	...
Perinatal	33 (8.3)	30 (7.0)	...
Other	42 (10.6)	34 (8.0)	...
Missing	18 (4.6)	38 (8.9)	...
Serious mental illness (excluding substance use disorder)	860 (74.3)	1604 (82.2)	<.0001
Substance use disorder (drugs or alcohol)	924 (79.8)	1478 (75.8)	.0094
Currently using substances	353 (30.5)	480 (24.6)	.0003
History of opioids	714 (61.7)	1172 (60.1)	.38
History of jail (2 years before eligibility)	304 (26.3)	468 (24.0)	.16

Abbreviations: HIV, human immunodeficiency virus; IQR, interquartile range; SUD, substance use disorder;

<sup>a</sup>The number of days an individual was enrolled in Medicaid.

2 years after program eligibility (Table 3). There were reduced, although not statistically significant, associations for ESLD ED visits and time to first ESLD event. We also observed significant decreases in hazard ratios for all-cause mortality (aHR = 0.65, 95% CI = .46–.92) and for liver-related deaths (aHR = 0.27, 95% CI = .09–.83) by NYNYIII placement status for 2 years after the first program eligibility.

There was a similar, although attenuated, trend for the same outcomes over a 5-year period (Table 3). Only hospitalizations for liver disease and ESLD were significantly reduced for placed versus unplaced persons. The remaining estimates were not statistically significant.

In our first sensitivity analysis, we looked at 2-year outcomes only among those who had 5 years of potential follow-up data, because different eligible NYNYIII populations have been targeted for placement at different times (Supplementary Table 3). Our results were similar in magnitude to those of our main

analysis for hospitalizations and mortality, although the latter was no longer a statistically significant association. Likewise, we no longer observed significant reductions in ED visits due to housing placement.

According to the second sensitivity analysis in which we limited our 2-year outcomes to those occurring before the introduction of DAAs (ie, outcomes through 31 December 2013) (Supplementary Table 3), among persons who first became eligible 2007–2011, the results were similar to our main analysis. However, only the reduction of the rate of ESLD ED visits due to housing placement was significant over a 5-year period.

Finally, we observed that a higher proportion of placed persons had at least 1 evaluation and management services visit after 2 years (73% vs 63%,  $P < .0001$ ), although after stabilized inverse probability of treatment weighting, there was no statistically significant association (adjusted risk ratio = 1.02, 95% CI = .98–1.06). After 5 years, 98% of both placed and

**Table 2. Leading Causes of Death Among Those With Hepatitis C Virus Infection by New York/New York III Placement Status, 2007–2014**

Cause of Death	Two-Year Outcomes				Five-Year Outcomes <sup>a</sup>			
	Overall Mortality		Premature Mortality <sup>b</sup>		Overall Mortality		Premature Mortality <sup>b</sup>	
	Placed N (%)	Unplaced N (%)	Placed N (%)	Unplaced N (%)	Placed N (%)	Unplaced N (%)	Placed N (%)	Unplaced N (%)
Total deaths	45 (4.0)	116 (6.0)	44 (97.8) <sup>c</sup>	112 (96.6) <sup>c</sup>	153 (13.7)	232 (11.9)	136 (88.9)	211 (91.0) <sup>c</sup>
Leading Causes of Death								
Drug use and accidental poisoning	9 (20.0)	27 (23.3)	9 (20.5)	27 (24.1)	29 (19.0)	45 (19.4)	29 (21.3)	44 (20.9)
HIV	9 (20.0)	24 (20.7)	9 (20.5)	24 (21.4)	30 (19.6)	44 (19.0)	25 (18.4)	42 (19.9)
Malignant neoplasms	8 (17.8)	14 (12.1)	7 (15.9)	13 (11.6)	25 (16.3)	35 (15.1)	21 (15.4)	27 (12.8)
Liver cancer <sup>d</sup>	3 (37.5)	5 (35.7)	3 (42.9)	5 (38.5)	11 (7.2)	9 (3.9)	9 (6.6)	7 (3.3)
Heart disease	6 (13.3)	11 (9.5)	6 (13.6)	9 (8.0)	18 (11.8)	27 (11.6)	14 (10.3)	22 (10.4)
Viral hepatitis	1 (2.2)	10 (8.6)	1 (2.3)	10 (8.9)	11 (7.2)	16 (6.9)	10 (7.4)	16 (7.6)
Chronic liver disease and cirrhosis	0 (0)	7 (6.0)	0 (0)	7 (6.3)	7 (4.6)	10 (4.3)	6 (4.4)	9 (4.3)
All other causes	12 (26.7)	23 (19.8)	12 (27.3)	22 (19.6)	33 (21.6)	55 (23.7)	31 (22.8)	51 (24.2)

Abbreviations: HIV, human immunodeficiency virus;

<sup>a</sup>Limited to those eligible through the end of 2012.

<sup>b</sup>Premature deaths are deaths among those <65 years of age.

<sup>c</sup>Proportion of total deaths.

<sup>d</sup>Proportion of cancer deaths.

**Table 3. Rate Ratios and Hazard Ratios for Liver-Related Healthcare Utilization and Mortality Among Those With Hepatitis C Virus by New York/New York III Placement Status, 2007–2014**

	Two-Year Outcomes						Five-Year Outcomes <sup>b</sup>					
	Number of Events		Unadjusted RR or HR	95% CI	Adjusted RR or HR <sup>a</sup>	95% CI	Number of Events		Unadjusted RR or HR	95% CI	Adjusted RR or HR <sup>a</sup>	95% CI
	Placed (N = 1158)	Unplaced (N = 1951)					Placed (N = 861)	Unplaced (N = 1312)				
Total												
Liver emergency department visit	437	704	<b>.69</b>	<b>.54–.89</b>	<b>.76</b>	<b>.61–.95</b>	701	1035	.93	.74–1.17	.99	.81–1.22
Liver hospitalization	1453	2802	<b>.61</b>	<b>.52–.71</b>	<b>.62</b>	<b>.54–.71</b>	2656	4141	<b>.81</b>	<b>.70–.95</b>	<b>.86</b>	<b>.75–.99</b>
End-stage liver disease emergency department visit	13	24	.73	.37–1.44	.71	.33–1.51	26	35	.99	.55–1.78	1.06	.59–1.92
End-stage liver disease hospitalization	60	237	<b>.29</b>	<b>.18–.47</b>	<b>.31</b>	<b>.20–.49</b>	164	342	<b>.51</b>	<b>.33–.78</b>	<b>.50</b>	<b>.34–.73</b>
First end-stage liver disease emergency department or hospitalization	52	103	.80	.57–1.11	.75	.53–1.05	94	141	.99	.76–1.28	.86	.65–1.13
All-cause mortality	45	116	<b>.67</b>	<b>.47–.94</b>	<b>.65</b>	<b>.46–.92</b>	153	232	1.05	.84–1.32	.98	.77–1.24
Liver-related mortality	<sup>c</sup>	18	.34	.12–1.01	<b>.27</b>	<b>.09–.83</b>	22	31	1.04	.57–1.88	.74	.38–1.44
End-stage liver disease death	<sup>c</sup>	<sup>c</sup>	1.03	.25–4.32	.51	.004–62.13	11	10	1.50	.56–4.05	1.64	.41–6.63

NOTE: Statistically significant results are in bold.

<sup>a</sup>Adjusted for demographics, substance use, HIV status, and pre-eligibility use of services, shelters, Medicaid, and incarceration events.

<sup>b</sup>Limited to those eligible through the end of 2012.

<sup>c</sup>Suppressed due to small numbers.



unplaced persons had at least 1 visit ( $P = .40$ ), and there was no statistically significant association (adjusted risk ratio = 1.00, 95% CI = .99–1.01).

## DISCUSSION

Placement into NYNYIII supportive housing was associated with a reduction in liver-related hospitalizations, ED visits, and mortality among persons with HCV. The impact of supportive housing decreased between 2 and 5 years for ED visits and mortality, although it did persist for hospitalizations. This attenuation may be explained by a decreasing proportion of placed persons still residing in NYNYIII housing over time. By the beginning of follow-up year 4, only 59% of placed persons still lived in a NYNYIII unit, and by the start of year 5, this was further reduced to 49%. Other studies of NYNYIII subpopulations have found that many who leave housing do so involuntarily or for legal, financial, or health problems [34], and that some placed persons may still fall into an unstable housing pattern (eg, shelter use, incarceration, hospitalizations), although eligible but unplaced persons have a much higher likelihood of unstable housing [24].

The finding that liver-related events were reduced among placed versus unplaced persons, even before the introduction of DAAs, supports the importance of placing people into supportive housing to reduce the number of liver-related health events and deaths. The intervention of permanent supportive housing, by providing housing stability along with case management and healthcare referrals, allows residents to focus on their connections to physical and mental healthcare and social services, which may help slow the progression of liver disease [2, 35]. Although we did not observe a significant association between housing placement and evaluation and management services visits, other types of healthcare and services not captured by Medicaid data may help to explain our findings.

An important component to the management of liver disease is to abstain from alcohol consumption and illicit drug use, because this can help to avoid further liver fibrosis [2, 36]. Although our data could not account for patterns of drug or alcohol use after eligibility, some studies have shown that placement into supportive housing is associated with reductions in the use of illicit substances and alcohol [37–40], although this evidence is mixed [41, 42]. Further evidence supporting this mechanism came from a prior evaluation of NYNYIII where placement into the program was associated with a reduced rate of drug- and alcohol-related ED visits and hospitalizations and an increased likelihood of initiating treatment for an SUD [19].

Persons with HIV and HCV coinfection are at higher risk for negative health outcomes. Our study showed HIV to be a leading cause of death among this cohort of persons with HCV infection. Other cohort studies of PWH have demonstrated that HCV seropositivity is associated with increased risk of an AIDS-defining opportunistic illness or HIV-related death [43] and all-cause

mortality [44]. However, supportive housing has shown to be beneficial for PWH. Hall et al [25] observed that among PWH, those in supportive housing had a reduced risk of progression to AIDS or death. Supportive housing has been associated with increased engagement in HIV care and with viral suppression for PWH [45, 46], which may in part be influenced by case management, because this service has been shown to improve antiretroviral adherence [47].

Although supportive housing placement was associated with lower mortality risk for 2 years, we did not observe differences in leading causes of mortality between placed and unplaced people. More than 90% of deaths for both groups were premature (<65 years of age), and the leading causes of mortality included drug and alcohol overdoses and HIV, which were similar to the findings of a study of NYC adults with HCV infection [48]. That analysis also found that persons with comorbid HIV and HCV infections died at younger ages than persons with only HCV infection, with more than half of deaths in the former group due to HIV/AIDS [48]. To reduce the mortality, particularly premature mortality, due to these causes, interventions (1) to improve screening for and treatment of drug and alcohol use and (2) to support and promote management of HIV disease among those with HCV infection should be scaled [2, 7].

This study has several limitations. First, we may not have captured all cases of HCV, either due to lack of screening, screening in a jurisdiction outside NYC, or persons having only received a positive antibody test. We also lacked data on potential interventions conducted at the program level (eg, Alcoholics Anonymous, HIV management services) geared towards improving health outcomes that are associated with HCV. In addition, persons who were not placed into NYNYIII housing had fewer days in which they were enrolled in Medicaid during the study's follow-up period. Although we accounted for this by using Medicaid-eligible days (ie, days enrolled in Medicaid) as an offset term in our models, unplaced persons may have been more likely to receive treatment for liver-related outcomes that were not captured in our data than placed persons. This evaluation uses an intention-to-treat framework; therefore, persons who are placed into the program may remain in supportive housing for varying amounts of time, which may bias our findings. Finally, although we were able to use stabilized IPTW and doubly robust estimators to account for differences in characteristics between the treated and untreated groups, there may be differences which were not measured that we were unable to account for in our models.

Despite these limitations, to the best of our knowledge, this is the first evaluation to test whether supportive housing placement was associated with reduced risk of liver-related health outcomes among persons with HCV. Another notable strength of this study is its large sample size and use of administrative datasets to measure objective endpoints. This analysis highlights the utility of including numerous, diverse data sources to evaluate a large-scale program.

## CONCLUSIONS

In this large evaluation of administrative data from NYC, we found that placement into permanent supportive housing reduced the number of liver-related hospital admissions, ED visits, and mortality among persons with HCV infection and a history of homelessness. Our findings provide important evidence that supportive housing programs should be expanded to help address HCV infection and poor liver-related health among persons experiencing homelessness.

## Supplementary Data

Supplementary materials are available at *The Journal of Infectious Diseases* online (<http://jid.oxfordjournals.org/>). Supplementary materials consist of data provided by the author that are published to benefit the reader. The posted materials are not copyedited. The contents of all supplementary data are the sole responsibility of the authors. Questions or messages regarding errors should be addressed to the author.

## Notes

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**Disclaimer.** This publication has been reviewed and approved by the New York State Department of Health. The views and opinions expressed in this article are those of the author(s) and do not necessarily reflect the official policy or position of the New York State Department of Health. Examples of analysis performed within this article are only examples. They should not be used in real-world analytic products.

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