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MAJOR ARTICLE

Identifying Geographic Areas of Washington, DC, With Increased Potential for Sexual HIV Transmission Among People With HIV With STIs and Concurrent Elevated HIV RNA: Data From the DC Cohort

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Background. The Undetectable = Untransmittable (U = U) campaign advances the goal of ending the HIV epidemic by promoting durable viral suppression and therefore reducing sexual transmission. We used geospatial analysis to assess the potential for sexual HIV transmission by ZIP code of residence in the District of Columbia (DC) using data from the DC Cohort Longitudinal HIV Study (DC Cohort), a city-wide cohort of persons with HIV (PWH).

Methods. DC Cohort participants aged ≥13 years were included in the study period between April 1, 2016, and March 31, 2018. Potential for sexual HIV transmission was defined as the proportion of participants with incident sexually transmitted infection (STI; gonorrhea, chlamydia, syphilis) and with HIV RNA ≥200 copies/mL from 9 months before to 3 months after STI diagnosis. We performed geographic information system (GIS) analysis to determine the ZIP codes with the highest potential for sexual HIV transmission.

Results. Of 3467 participants, 367 (10.6%) had at least 1 incident STI, with 89.4% residing in 11 of the 20 residential ZIP codes in DC. Of the 367 participants with an incident STI, at least 1 HIV RNA was available for 348 (94.8%). Ninety-seven (27.9%) individuals with an incident STI had HIV RNA ≥200 copies/mL in the defined time window. Of these 97, 66 (68.0%) resided in 5 of the 20 DC ZIP codes.

Conclusions. In DC, 5 ZIP codes of residence accounted for the majority of the estimated potential for HIV transmission among participants in the DC Cohort. These results support focused neighborhood-level interventions to help end the HIV epidemic.

Keywords. geospatial; HIV; HIV RNA; sexually transmitted infection.

The Undetectable = Untransmittable (U = U) campaign promotes durable viral suppression (VS) of HIV as a strategy for reducing sexual transmission and ending the HIV epidemic (EHE) [1]. Overwhelming evidence supports that when people with HIV (PWH) achieve and sustain VS, their risk of sexual HIV transmission is essentially eliminated [2–4]. Additionally, VS among PWH promotes maintenance of immune reconstitution and achievement of improved health outcomes [5]. Washington, DC, has the highest jurisdictional prevalence of HIV in the United States (1.8%) [6]. Sexual transmission is the most common mode of acquiring HIV infection in DC (90% of newly diagnosed cases in 2019) [6]. At the same time, incidence rates of all sexually transmitted infections (STIs) have increased among PWH in DC from 2014 to 2019 [6, 7]. With widespread antiretroviral use, HIV incidence in DC has declined since 2007; however, there are still ~280 new cases of HIV annually [6].

The District of Columbia Department of Health (DC DOH) monitors HIV care continuum outcomes including achievement of VS among PWH and STI incidence within DC. The DC DOH has developed an updated locally specific response for EHE called "DC Ends HIV." The target goals are for 95% of District residents with HIV to know their status, 95% who know their status to be in treatment, 95% who are in treatment to be virally suppressed, and ultimately reducing new HIV diagnoses to <130 annually by 2030 [8]. In recent years, VS among all PWH in DC in 2019 remained at 66% overall and 85% among

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PWH engaged in medical care [6]. The goal of consistent VS among PWH remains a pillar of the U = U campaign and a key strategy of "DC Ends HIV" [8, 9].

The incidence of STIs, including chlamydia, gonorrhea, and syphilis, is rising nationally and in DC [10, 11]. STIs can increase the risk of both acquiring and transmitting HIV, and previous studies have shown that a history of any STI is significantly associated with subsequent HIV infection among both MSM and non-MSM populations [12–14]. PWH who have both uncontrolled HIV RNA and an STI concurrently likely play a large role in ongoing HIV transmission [6, 15]. The occurrence of a new STI indicates that an individual has participated in sexual activity without effective barrier protection. If occurring in a person with HIV without VS, this may lead to HIV transmission from that individual to an HIV-uninfected partner who is not on HIV pre-exposure prophylaxis (PrEP).

A recent study using DC HIV surveillance data visualized geographical hotspots for unsuppressed HIV among different population groups in DC [16]. Previous work using data from the DC Cohort Longitudinal HIV Study (DC Cohort) has utilized geographic information systems (GIS) to measure the proximity between participants and their health care providers, highlighting gaps between retention in care and VS among certain geographic areas and emphasizing the importance of local spatial analysis to identify priority areas for targeted efforts to reduce barriers to HIV care [17]. This is the first analysis combining STI incidence data, used as proxy for condomless sexual encounters, with VS data from the city-wide longitudinal cohort of PWH. While the rate of HIV per 100 000 persons by ZIP code is reported annually by the DC DOH, the proportion of PWH by ZIP code with both incident STI and unsuppressed HIV RNA has not previously been reported. We used a geospatial approach to analyze these complementary sets of data to meet our objective of identifying areas of highest potential for sexual transmission of HIV in DC.

METHODS

Patient Consent

The DC Cohort enrolls people with diagnosed HIV from 15 HIV clinics in Washington, DC, through a written informed consent process [18]. Postlinked data also included HIV RNA test results that participants received from both DC Cohort and non–DC Cohort providers. The details of this linkage have been published previously [19]. The study protocol was approved by the George Washington University Institutional Review Board (IRB), the DC Department of Health IRB, and the IRBs of the individual study sites.

Study Population and Design

Participants were eligible for the analysis if they were DC residents, active participants in the DC Cohort, and >13 years of age at the time of enrollment. Participants consent to have their demographic and clinical data linked to surveillance data from the DC DOH, inclusive of STI data, CD4 cell counts, and HIV RNA values. This allows for the capture of incident STI diagnoses reported at sites other than the usual location of HIV care. Participants with newly diagnosed chlamydia, gonorrhea, or syphilis between April 1, 2016, and March 31, 2018, were defined as incident STI cases. An incident case of chlamydia or gonorrhea was identified by a positive nucleic acid amplification test (NAAT) or culture on urogenital or extragenital specimens. A subsequent new case was accepted as such if there was a positive test ≥30 days after the previous positive test. An incident case of syphilis was defined as having (i) a positive nontreponemal test (NTr) titer of ≥1:8 with a previous nonreactive NTr, (ii) a 4-fold increase in the NTr titer of the previous test, or (iii) a positive treponemal antibody test (Tr) if an NTr titer was ≥1:8 and the previous Tr test was negative. To identify potential for sexual HIV transmission, we evaluated VS within the window of time aiming to capture the 6-month U = U consensus definition (The U = U consensus definition states that "the risk of HIV transmission from a person living with HIV (PLHIV), who is on Antiretroviral Therapy (ART) and has achieved an undetectable viral load in their blood for at least 6 months is negligible to non-existent") [9]. However, in order to consider time gaps between STI acquisition and testing while accounting for routine 6-month HIV lab schedules, the window was expanded for our study. For this analysis, HIV RNA measurements were shifted from 9 months before to 3 months after the first incident STI diagnosis using all available quantitative HIV RNA lab results within the U = U window. Any HIV RNA value ≥200 copies/mL was considered unsuppressed and potentially contributing to HIV transmission [20].

Data Analysis and Visualization

Demographic characteristics, including age race/ethnicity, current gender, antiretroviral status, and transmission risk, were reported as frequency (%) for categorical data and median (interquartile range) for continuous data, using Pearson's chi-square test or the Fisher exact test (where appropriate due to small cell size), and the Wilcoxon rank-sum test, respectively. Differences by factors are shown by group category for those with ≥1 incident STI and without any incident STI during the observation period. For participants with an incident STI, an additional comparison of factors was explored for differences in VS. All statistical analyses were conducted in SAS 9.4 (SAS, Cary, NC, USA). P values <.05 were considered statistically significant.

Only participants with an incident STI during the observation period were included in data visualizations by ZIP code. Any HIV RNA ≥200 copies/mL occurring during the U = U window around the date of the incident STI was considered a potential HIV transmission encounter. Choropleth maps were

chosen to help visualize the variability in potential HIV transmission across Washington, DC, using a range of colors in proportion with the outcomes associated with each ZIP code. Residential ZIP codes with <10 participants were pooled into 1 category to support participant confidentiality. We used ArcGIS 9.4 (ESRI, Redlands, CA, USA) to generate geospatial maps to present STI prevalence and unsuppressed HIV RNA data (frequency and percentage of total participants) by ZIP code level. Tiger shapefiles that are based on standard ZIP code boundaries were used to identify and map DC area residential ZIP codes. Several federal agencies in the DC area possess unique ZIP codes to accommodate mail services yet are not shared by residential areas. These ZIP codes were not included in our analysis because they lack residential demographic data.

The rates of burden of STI by ZIP code were significantly different. For this reason, we presented choropleth map results using both percentages and counts to compare the prevalence, in addition to absolute numbers, in the participant population with incident STI. This strategy allowed for a visual comparison of a more standardized approach using proportions, while not obscuring the absolute number of outcomes present in each ZIP code. A darker color represents a higher number of participants with incident STI as well as the potential for HIV transmission. Shaded gray regions are areas where no participants reside, which includes federal land within DC.

RESULTS

A total of 3467 active participants with available ZIP codes within DC were assessed for incident STI, with 367 or 10.6% having ≥1 incident STI during the study period. Compared with those without any STIs, those with ≥1 incident STI were younger (median age, 42.4 vs 54.2 years; $P < .0001$), more likely to be cisgender male (86.4% vs 63.9%; $P < .0001$), and more likely to report male-to-male sexual contact as the mode of HIV acquisition (72.5% vs 31.92; $P < .0001$). White race was more frequently represented among those with an STI (20.4.%) than among those without an STI (8.5%), and Black participants were less frequently represented among those with an STI than among those without (68.7% vs 83.5%; $P < .0001$). Homelessness or temporary housing was more common among those with an STI (18.9% vs 9.1%; $P < .0001$) (Table 1).

Of 348 participants with an incident STI and ≥1 HIV RNA available, 97 (26.4%) had ≥1 HIV RNA ≥200 copies/mL in the U = U window, indicating potential for HIV transmission. Of these, 81.4% were male, 81.4% Black, 13.4% White, 60.8%

Table 1. Characteristics of Participants With and Without STI Incident STI Washington, DC Cohort, 2016–2018

	Total PWH, No. (%)	No Incident STI, No. (%)	Incident STI, No. (%)	*P* Value
No. of participants	3467	3100	367	
Characteristics				
Age, median, y	53.4 (44.0–60.0)	54.2 (45.7–60.5)	42.4 (33.8–52.4)	<.0001
Age category				<.0001
13–17 y	9 (0.3)	9 (0.3)	0 (0.0)	
18–34 y	362 (10.4)	257 (8.3)	105 (28.6)	
35–54 y	1590 (45.9)	1393 (44.9)	197 (53.7)	
55+ y	1506 (43.4)	1441 (46.6)	65 (17.7)	
Race/ethnicity				<.0001
Non-Hispanic Black	2839 (81.9)	2587 (83.5)	252 (68.7)	
Non-Hispanic White	337 (9.7)	262 (8.5)	75 (20.4)	
Hispanic	180 (5.2)	149 (4.8)	31 (8.5)	
Other	46 (1.3)	44 (1.4)	2 (0.5)	
Gender (current)				<.0001
Cisgender male	2298 (66.3)	1981 (63.9)	317 (86.4)	
Cisgender female	1086 (31.3)	1052 (33.9)	34 (9.3)	
Transgender female	78 (2.25)	62 (2.0)	16 (4.4)	
Transgender male	5 (0.1)	5 (0.2)	0 (0.0)	
ARV status				.3137
No	162 (4.7)	141 (4.6)	21 (5.7)	
Yes	3305 (95.3)	2959 (95.5)	346 (94.3)	
HIV transmission risk				<.0001
MSM	1234 (35.6)	968 (31.2)	266 (72.5)	
IDU	234 (6.8)	226 (7.3)	8 (2.2)	
Heterosexual	1220 (35.2)	1175 (37.9)	45 (12.3)	
Other/unknown	779 (22.5)	731 (23.6)	48 (13.1)	

The *P* values shown are derived from chi-square statistics assessing whether at least 2 groups are significantly different.

Abbreviations: ARV, antiretroviral; IDU, injection drug use; MSM, men who have sex with men; PWH, people with HIV; STI, sexually transmitted infection.

Table 2. Characteristics of Participants Within Incident STI Subgroup Comparing Those With and Those Without ≥1 Unsuppressed and Transmittable Viral Load Measurement During the U = U Window, DC Cohort 2016–2018

	Total	HIV RNA <200 Copies/mL, No. (%)	HIV RNA ≥200 Copies/mL, No. (%)	*P* Value
No. of participants	348	251	97	
Characteristics				
Age, median, y	41.9 (33.8–52.4)	43.2 (34.9–52.8)	38.3 (31.7–48.9)	.0060
Age category				.0303
13–17 y	0 (0.0)	0 (0.0)	0 (0.0)	
18–34 y	101 (29.0)	63 (25.1)	38 (39.2)	
35–54 y	186 (53.5)	140 (55.8)	46 (47.4)	
55+ y	61 (17.5)	48 (19.1)	13 (13.4)	
Race/ethnicity				.0210
Non-Hispanic Black	239 (68.7)	160 (63.8)	79 (81.4)	
Non-Hispanic White	70 (20.1)	57 (22.7)	13 (13.4)	
Hispanic	30 (8.6)	25 (10.0)	5 (5.2)	
Other	2 (0.6)	2 (0.8)	0 (0.0)	
Gender (current)				
Cisgender male	303 (87.1)	226 (90.0)	77 (79.4)	.0209
Cisgender female	29 (8.3)	17 (6.8)	12 (12.4)	
Transgender female	16 (4.6)	8 (3.2)	8 (8.3)	
ARV status				.0513
No	19 (5.46)	10 (3.98)	9 (9.28)	
Yes	329 (94.54)	241 (96.02)	88 (90.72)	
HIV transmission risk				.0137
MSM	254 (73.0)	195 (77.7)	59 (60.8)	
IDU	7 (2.0)	5 (2.0)	2 (2.1)	
Heterosexual	40 (11.5)	23 (9.2)	17 (17.5)	
Other/unknown	47 (13.5)	28 (11.2)	19 (19.6)	
Incident STI[a]				
Chlamydia	187 (53.7)	132 (52.6)	55 (56.7)	.4904
Gonorrhea	212 (60.9)	153 (61.0)	59 (60.8)	.9820
Syphilis	91 (26.2)	66 (26.3)	25 (25.8)	.9209

The *P* values shown are derived from chi-square statistics assessing whether at least 2 groups are significantly different.

Abbreviations: ARV, antiretroviral; IDU, injection drug use; MSM, men who have sex with men; STI, sexually transmitted infection.

[a]Incident STI cases are not mutually exclusive.

men who have sex with men (MSM), and 17.5% heterosexual. The most common STI was gonorrhea (60.9%), followed by chlamydia (53.7%) and syphilis (26.2%), with no significant ($P > .05$) difference between suppressed and unsuppressed HIV RNA groups. A viral load ≥200 copies/mL in the U = U window was overrepresented among younger, female, Black, and heterosexual participants (Table 2).

There are 30 standard ZIP codes within Washington, DC, with 23 providing available demographic data, indicating a residential population. DC Cohort participants lived in all 23 of those DC ZIP codes. Of the 367 participants with incident STI, 89.4% (328/367) lived in 11 ZIP codes (Figure 1A, red and pink). This figure tracked with the 89.4% (3098/3467) of total DC Cohort participants residing in the same 11 ZIP codes (Supplementary Table 1). Among the 367 participants with an incident STI, ≥1 HIV RNA lab was available in the U = U window for 348 (94.8%), who lived in 20 of the 23 DC ZIP codes. Among participants with ≥1 HIV RNA ≥200 copies/mL in the U = U window, 68.0% (66/97) resided in 5 of the 23 Washington, DC, ZIP codes. The prevalence of unsuppressed HIV RNA in the U = U window among those with an STI did not immediately reveal distinct groupings or patterns of potential HIV transmission (Figure 1B, medium and dark blue). However, additional review of the absolute number of PWH with an incident STI and HIV RNA ≥200 copies/mL, rather than the proportion, indicated more distinct grouped areas (Figure 1C, medium and dark green).

DISCUSSION

In this large urban cohort, we found that PWH with an incident STI and an HIV RNA ≥200 copies/mL in the U = U window were in limited geographic areas. These ZIP codes are neighborhoods contained within Wards 7 and 8, municipalities that reside east of the Anacostia River. Wards 7 and 8 include a majority Black community that has higher rates of poverty and has experienced significant inequities in health outcomes, including distance to HIV-related care [17, 21]. Furthermore,

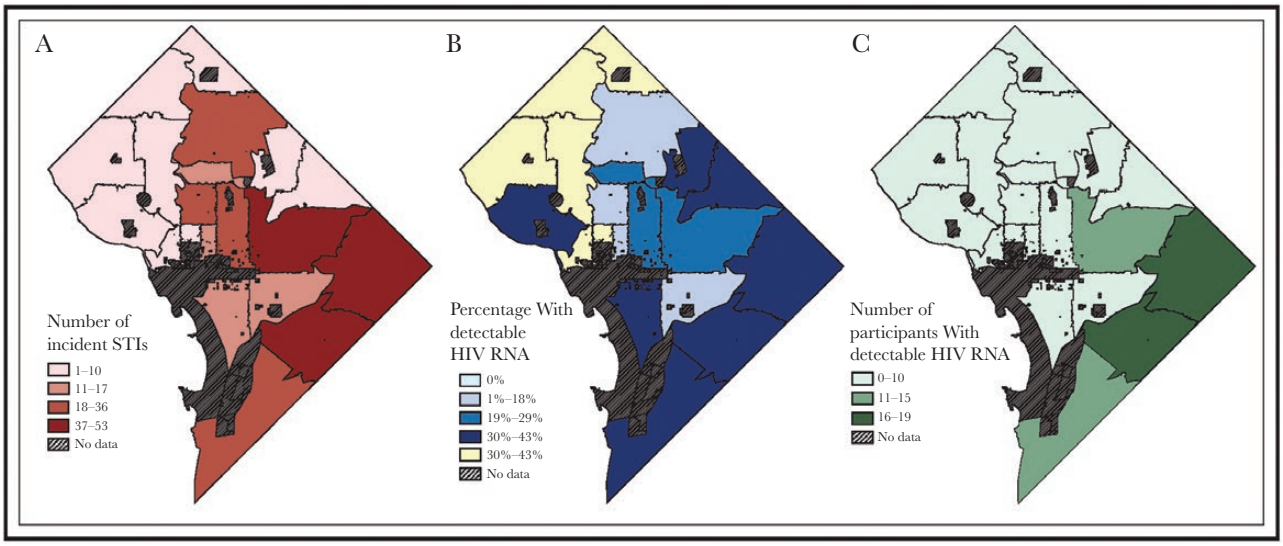

Figure 1. Maps of DC by ZIP code, with (A) number of DC Cohort participants with incident STI; (B) percentage with HIV RNA >200 copies/mL; and (C) number with HIV RNA >200 copies/mL among those with an incident STI. Abbreviation: STI, sexually transmitted infection.

we demonstrate a potential geographical imbalance in incident STI compared with incident STI with HIV RNA >200 [22]. We found that the ZIP codes with the highest incident STI cases did not consistently align with those with the highest number of individuals with potential for HIV transmission. The areas of highest transmission risk identified in our study, those areas with the greatest number of PWH with incident STIs with unsuppressed viral loads, were similarly east of the Anacostia, identified as "geographic core areas of coinfection" by Das et al. for their non-MSM participants but not fully overlapping for the MSM participants in Washington, DC [16].

Despite evidence for U = U and treatment as prevention, incident STIs occurring during periods of viremia represent events that carry an increased risk of HIV transmission [12]. To achieve the new goals of "DC Ends HIV" in the District of Columbia, enhanced and timely prevention, rapid testing, and partner treatment for HIV and STIs are necessary [8]. Previously, we described significant yearly increases in STI incidence rates observed across all adult age groups in the DC Cohort [12, 23]. Identifying geographically specific information regarding STIs and potential for HIV transmission allows for expansion of resources on treatment and prevention of HIV, including outreach for U = U, PrEP, and STI prevention campaigns. Additional studies incorporating individual-level behavioral data are ongoing.

The strengths of this analysis include the linkage of citywide data on STI incidence and longitudinal HIV care and the use of the most recent available ZIP codes associated with residence location. We were able to capture ongoing community burden and to estimate sexual transmission risk by geographic areas. Our study advances the EHE goals of using community-level metrics to monitor HIV VS and inform treatment linkage and adherence promotion efforts. This analysis has direct utility for public health practice and can be used to better apply and evaluate the impact of public health interventions.

Our study has several limitations stemming from the nature of our data, which provide an estimation of the potential for HIV transmission based only on laboratory parameters. STI screening is not fully standardized across locations of care in DC, and this variability is not accounted for in this analysis. Additionally, the anatomic site of chlamydia or gonorrhea was not available to allow distinction between pharyngeal, urethral, vaginal, or anal infections. The true frequency and type of condomless sex exposure among persons with unsuppressed HIV and partners without PrEP was unknown, and the distribution of very high viral loads that may be associated with an elevated risk of potential sexual transmission was not addressed [24]. Our analysis only includes participants engaged in care to some degree, and it is possible that those PWH not engaged in care may be at higher risk for transmission of HIV and STI [25]. While ZIP codes were available for participant residence location, these areas are not necessarily equated to where sexual risk behaviors occur. In order to be effective, U = U also relies on disseminating the strategy to PWH through community outreach and health care providers. This includes adhering to STI screening recommendations and assessing HIV RNA among PWH who are diagnosed with an STI, thereby assessing HIV transmission risk potential. This also includes emphasizing the importance of ART adherence to promote the U = U strategy. This study was unable to determine the difference in population based on access or familiarity with the U = U strategy among those regarded as having the potential for HIV transmission.

Despite the limitations, Choropleth maps provide visual-based health data by enumeration units (ZIP codes) that are familiar among HIV care providers and their patients. Integrating maps among participant health outcomes as well as community health offers a broader perspective of needs in geographic areas.

Our findings highlight the importance of understanding factors affecting sexual health and using complementary data approaches in order to identify the areas at highest need of additional support in order to achieve wider condom use, HIV viral suppression, and expansion of PrEP, toward improving clinical outcomes for PWH and ending the HIV epidemic.

CONCLUSIONS

In Washington, DC, 5 ZIP codes of residence accounted for 68.0% of the estimated potential HIV transmission burden among DC Cohort participants. The longitudinal data provided by this cohort study in a focused geographic area allow for a visual representation of VS among those with incident STI, advancing efforts to monitor and evaluate the U = U campaign and the Ending the HIV Epidemic initiative. Estimates of potential for HIV transmission by ZIP code of residence allow for focused, neighborhood-level interventions that may strengthen efforts to end the HIV epidemic.

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.

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