



Geographic Variations in Retention in Care among HIV-Infected Adults in the United States

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Abstract

Objective

To understand geographic variations in clinical retention, a central component of the HIV care continuum and key to improving individual- and population-level HIV outcomes.

Design

We evaluated retention by US region in a retrospective observational study.

Methods

Adults receiving care from 2000–2010 in 12 clinical cohorts of the North American AIDS Cohort Collaboration on Research and Design (NA-ACCORD) contributed data. Individuals were assigned to Centers for Disease Control and Prevention (CDC) regions by residential data (10 cohorts) and clinic location as proxy (2 cohorts). Retention was ≥ 2 primary HIV outpatient visits within a calendar year, >90 days apart. Trends and regional differences were analyzed using modified Poisson regression with clustering, adjusting for time in care, age, sex, race/ethnicity, and HIV risk, and stratified by baseline CD4⁺ count.

Results

Among 78,993 adults with 444,212 person-years of follow-up, median time in care was 7 years (Interquartile Range: 4–10 years). Retention increased from 2000 to 2010: from 73% (5,000/6,875) to 85% (7,189/8,462) in the Northeast, 75% (1,778/2,360) to 85% (1,630/1,880) in the Midwest, 68% (8,451/12,417) to 80% (9,892/12,304) in the South, and 68% (5,147/7,520) to 72% (5,147/7,520) in the West. In adjusted analyses, retention improved over time in all regions ($p < 0.01$, trend), although the average percentage improved less in the West and South vs. the Northeast ($p < 0.01$).

Conclusions

In our population, retention improved, though regional differences persisted even after adjusting for demographic and clinical factors. These data demonstrate regional differences in the US which may affect patient care, despite national care recommendations.

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Data Availability: Data are from the NA-ACCORD cohort collaboration of IeDEA (International epidemiologic Datab Evaluate AIDS), whose authors may be contacted at <http://statepiaps.jhsph.edu/naaccord/Collaboration/index.html>. sheet must be submitted, reviewed, and approved by the Executive and Steering Committees of NA-ACCORD before access/data sharing are allowed. This is a requirement of all participating cohort IRB approvals, as well as the study IRB approval from the Johns Hopkins University School of Medicine, ensuring secure, timely, and ethical sharing of the cohort's data. Due to ethical restrictions, data are available upon request. The NA-ACCORD's data practices have been outlined in the literature (<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2820873/>). Interested researchers may submit requests for data to the project manager, who will direct the collaborative process through the Administrative, Data Management, and Epidemiology/Biostatistics Cores (afreeman@jhu.edu).

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Introduction

Mapping health outcomes and identifying geographic variations in care are useful tools in public health, assisting decisions in identifying locales in greatest need of resources.[1–7] The field of HIV epidemiology has been no exception, and analyzing geographic variation in HIV incidence, extent, severity, and intervention effectiveness have yielded insights into the character and trajectory of the pandemic.[8–16] In the U.S., HIV prevalence, incidence, disease progression, treatment, and mortality have been noted to differ across geographic regions and individual states.[17–21]

Retention in care is associated with improved access to antiretroviral therapy (ART), greater likelihood of virologic suppression, and less rapid HIV disease progression.[22–27] Similarly, the same demographic, clinical, and socioeconomic factors (i.e., age, sex, Black race, higher CD4 count, and unstable housing status) have been repeatedly associated with suboptimal retention in care contexts. However, these analyses have rarely focused on geographic heterogeneity as a potential source of clinical differences and have incorporated these data by adjusting for clinic site in multi-site analyses or examining relatively small numbers of jurisdictions.[28–39] Further, some of the studies in which these patterns of retention were discerned may have cohort characteristics which could affect clinic attendance such as state Medicaid funding levels or local social stigmas (e.g., a history of discrimination toward sexual minorities) that could limit their external generalizability to persons living with HIV/AIDS (PLWHA) in the United States. Nevertheless, recent major policy initiatives, including the National HIV/AIDS Strategy (NHAS), have identified improving retention, and targeting impediments to these improvements, as goals central to improving outcomes across the HIV Care Continuum in the U.S.[40–43]

Yet retention in care requires consistent and ongoing interaction with the healthcare system, a process which may include many obstacles which differ geographically (due to demographic, economic, risk behavior, political, and cultural factors).[9,20] In considering these issues, our aim was to describe the geography of clinical care experience over time in order to provide evidence for evaluating benchmarks of national HIV policy goals and to better understand factors that are pertinent to policy interventions designed to improve retention in HIV care.[42] We therefore quantified the geographic heterogeneity of retention between 2000 and 2010 within a large and geographically diverse HIV cohort that is demographically similar to PLWHA in the U.S.[45]

Methods

Population and study design

The North American AIDS Cohort Collaboration on Research and Design (NA-ACCORD) represents the United States component of the International epidemiologic Databases to Evaluate AIDS (IeDEA) project. The NA-ACCORD began collecting data from single-site interval and clinical cohorts in 2006.[46] The Institute of Medicine of the National Academies (IOM) has identified the NA-ACCORD, due to its size and demographic similarity with PLWHA in the U.S., as one of 12 data systems appropriate for research on HIV care.

assess quality of care goals, such as improving clinical retention, in the NHAS and Affordable Care Act [24] Details of the collection and submission process for the NA-ACCORD have been published previously.[47] Briefly, clinical, demographic, and geographic data from 25 cohorts are transmitted to a centrally-administered Data Management Core annually where all data are harmonized. Data undergo quality control for completeness and accuracy, including measures to reduce the probability that an individual was concurrently participating in more than one clinical cohort. The activities of the NA-ACCORD and participating cohorts have been reviewed and approved by their respective local institutional review boards and by the Johns Hopkins School of Medicine institutional review board. Written consent was either obtained individually, or else waivers of consent were obtained through each site's respective local institutional review board. All data were de-identified prior to analysis.

Among clinical cohorts, only patients with ≥ 2 HIV primary care visits within 12 months were enrolled into the NA-ACCORD. The NA-ACCORD population to patients successfully linked to and established as "in care" proximal to cohort entry.[24,47]

Adult participants who had ≥ 1 HIV primary care visit between January 2000 and December 2010 were included in this retrospective cohort study. Classic prospective cohorts were excluded to allow an exclusive focus on patterns of patient retention in clinical cohorts. Canadian cohorts were also excluded. The 12 included clinical cohorts were comprised of patients from U.S. states, Washington, D.C., and Puerto Rico, 818 of 887 US 3-digit ZIP Code Tabulation Areas (ZCTA), and 167 clinics located in areas of dense population across the country.

Our nested study was reviewed by the Johns Hopkins Bloomberg School of Public Health institutional review board, and deemed non-human-subject/non-research because it was a secondary analysis of existing, anonymized/de-identified data.

Retention measures, factors associated with retention, and follow-up

The outcome for our analysis was clinical retention in care ("retention"), defined using the IOM indicator: ≥ 2 HIV primary care visits within a calendar year, ≥ 90 days apart.[24] This measure was used because it is the same as that adopted in the National HIV/AIDS Strategy. We have previously evaluated the strong agreement of this indicator with DHHS indicators and with proxies.[25,48] Only HIV primary care encounters were used to define retention. Other outpatient encounter types, including subspecialty care, emergency department, dental, mental health, nursing, nutrition, orientation, pharmacy, social work/counseling, substance abuse, and other/unknown outpatient encounters, were not used for these analyses. Inpatient visit laboratory only visits were also excluded.

Participant age (<40 , 40–49, 50–59, and ≥ 60 years), sex, race/ethnicity (White, Black, Hispanic, or other/unknown), HIV risk factor (male sexual contact with men (MSM), injection drug use [IDU], heterosexual contact, or other/unknown), recent (≥ 6 months in a year (≥ 3 antiretroviral drugs from ≥ 2 classes, or a triple nucleoside/nucleotide reverse transcriptase inhibitor (NRTI) regimen containing abacavir or tenofovir), first CD4⁺ cell count during each year of follow-up, last HIV-1 RNA measurement during each year of follow-up, and geographic location of residence (US Centers for Disease Control (CDC)-defined regions and 3-digit ZCTA) were included in analyses of factors by which clinical retention may have differed. The composition of the study population is described below.

ART receipt and CD4⁺ cell count were used in secondary analyses as baseline covariates for stratification indicating health status and access to care at cohort enrollment; HIV-1 RNA was excluded from regression analyses due to its putative role as a time-dependent confounder in the longitudinal relationship between demographic and HIV risk characteristics and retention. Geographic location of patient residence was collected at cohort entry and was not allowed to vary over time due to limited availability of residential movement data over the study period.

Individual data were summarized into one observation per year between 2000 (at the earliest) and the final encounter prior to the end of 2010. The initial year of care was excluded if the patient entered in the final quarter of a calendar year (and were ineligible to be "retained" in their year of entry). Year of death during the study period was excluded from analyses due to not being uniformly "at risk" for successful retention in that year. Follow-up time ranged between 1 and 11 person-years; individuals contributed multiple outcomes while under observation.

Additional geographic information

Location of patient residence by ZCTA was collected by individual clinical cohorts. Data consistency checks were performed to ensure that ZCTA of residence corresponded correctly with state of residence (as ZCTAs may be aggregated to the state along coterminous boundaries). State of residence was used to assign patients to geographic regions of the U.S. based on US Census Bureau definitions. US CDC-defined regions were: Northeast: CT, ME, MA, NH, NJ, NY, PA, RI, VT; Midwest: IL, IN, IA, KS, MI, MN, MO, NE, ND, OH, SD, WI; South: AL, AR, DE, DC, FL, GA, KY, LA, MD, MS, NC, OK, SC, TN, TX; West: AK, AZ, CA, CO, HI, ID, MT, NV, NM, OR, UT, WA, WY.[49] Demographic, geographic, and economic characteristics of the ZCTAs were derived from 2000 and 2010 US decennial census estimates and assigned as follows: for years 2000–2007: 2000 census; for years 2008–2010: from the 2010 census; and for years 2004–2007: mid-point estimates between census years 2000 and 2010. Census-derived population-level variables included median age within the ZCTA and proportions of the population that were of female sex, of Black race, residing in a rural area, and living below the Federal poverty level. Rural areas and the poverty level were defined according to US Census Bureau standards.[50] For ZCTA-level analyses, individual characteristics for NA-ACCORD participants were aggregated to the ZCTA level as median age in the sample, and the proportion of the s

were of female sex, of Black race, and that had IDU as an HIV risk factor within the ZCTA.

For participants from 2 clinical cohorts (N = 35,131) whose residential data was unavailable, clinic location was used as state of residence, but not for ZCTA; individuals from these cohorts were included in descriptions and analyses of region state-level differences in retention but not in analyses using ZCTA-level data.

Statistical models and methods

Regional differences in the percentage of patients clinically retained within strata of demographic and clinical characteristics detected by χ^2 test. Modified Poisson regression using a Generalized Estimating Equation (GEE) was used to assess trends and determine the relative risks (RR) and 95% confidence intervals (CI) of retention based on demographic and factors at the individual level.[51] An unstructured working correlation was used for repeated outcomes within individual GEE regression.[52,53] Time during the study period (i.e., study year) was included in models as a restricted cubic spline knots (at 2, 6, and 10 years) and as a categorical term for predictive margins.[54] All individual-level models were also adjusted for total time contribution to the study (to account for possible cohort effects) and for contributing cohort site (to account for clinical practice differences). All proportions at the ZCTA level were mean-centered to ease interpretation in logistic regression modeling using GEE. In secondary analyses, the relationship between baseline CD4+ count and ART use with retention was assessed to explore regional differences in retention trajectories by initial access to care and late diagnosis. Interaction region-by-baseline factors were included with the full Poisson regression model used in primary analyses at the individual level. Missing baseline CD4+ counts were multiply imputed using a predictive mean model regression including baseline age, race/ethnicity, HIV risk factor, ART use, and cohort site.[55]

Population-averaged effects are generally viewed as more germane to policy decisions, and there is evidence that mixed-effects approaches may induce bias in this context.[56,57] Thus, the population-averaged model was employed here. ZCTA-level differences in proportions retained were also explored using logistic regression with GEE, adjusting for aggregated individual-level characteristics.[58,59] Additional details of Poisson and logistic regression models with GEE at the individual and ZCTA levels, respectively, are available in the Appendix (S1 File). Maps were generated using ArcGIS version 10.1 (Environmental Systems Research Institute, Redlands, CA) and statistical analyses were performed using Stata version 12 (StataCorp, College Station, TX).

Results

Among 78,993 adults with 444,212 person-years of follow-up, the median time in care was 7 (Interquartile Range: 4–9) years. The Midwest sample had the smallest percentage of regional prevalent HIV cases with 3.7% (3,583/97,711); the West had the largest percentage with 7.5% (12,037/159,523), using CDC data for prevalent HIV cases from 2009 as the denominator (the latter which all 12 clinical cohorts contributed data).[49] There were significant differences between US geographic regions in percentage of person-time retained for each demographic and clinical characteristic evaluated (Table 1).

Factor	Total Person-Years (PY) (% PY censored)	Northwest % PY Retained (% PY censored)	Midwest % PY Retained (% PY censored)	South % PY Retained (% PY censored)	West % PY Retained (% PY censored)
Total	7,444,212 (100)	79 (22)	81 (17)	73 (48)	75 (26)
Age (years)*					
<39	118,828 (27)	69 (24)	72 (24)	63 (28)	62 (27)
40–49	186,389 (25)	77 (26)	81 (27)	73 (26)	70 (26)
50–59	114,764 (26)	83 (28)	84 (27)	80 (28)	76 (24)
≥60	44,413 (12)	88 (29)	89 (25)	88 (29)	83 (29)
Sex					
Male	367,048 (83)	79 (14)	80 (86)	74 (82)	71 (92)
Female	77,164 (17)	77 (28)	83 (14)	69 (16)	67 (12)
Race/Ethnicity					
Non-Hispanic White	183,580 (41)	80 (28)	83 (42)	77 (38)	71 (82)
Non-Hispanic Black	294,782 (44)	77 (31)	78 (48)	71 (35)	66 (18)
Hispanic	48,120 (11)	78 (18)	84 (8)	73 (27)	71 (12)
Other/Low	17,720 (4)	79 (2)	81 (8)	72 (2)	67 (8)
HIV Risk Factor					
MSM	152,881 (34)	79 (28)	83 (28)	73 (28)	69 (28)
IDU	86,701 (18)	76 (28)	76 (18)	72 (28)	69 (14)
History	35,889 (22)	79 (28)	82 (17)	88 (23)	86 (13)
Other/Low	109,351 (25)	79 (18)	81 (28)	79 (28)	77 (21)
CD4+ Cell Count (cells/mm ³)					
<200	73,338 (17)	81 (18)	85 (15)	74 (18)	76 (15)
200–349	76,340 (17)	84 (18)	87 (15)	79 (17)	74 (17)
350–499	77,588 (17)	85 (17)	89 (18)	81 (17)	74 (18)
≥500	134,222 (28)	86 (28)	90 (21)	82 (28)	74 (28)
Missing	63,523 (18)	49 (18)	56 (23)	50 (23)	47 (16)
HIV-1 RNA (copies/mL) ^b					
>200 copies	176,823 (42)	79 (41)	81 (28)	70 (44)	69 (34)
<200 copies	188,982 (45)	88 (47)	82 (42)	80 (38)	77 (54)
Missing	48,429 (15)	48 (12)	58 (25)	54 (17)	48 (12)
ART Receipt (12 months) ^c					
<6 months ART	170,251 (38)	59 (37)	62 (37)	55 (41)	53 (38)
≥6 months ART	273,961 (82)	88 (63)	92 (63)	88 (59)	80 (62)

Percent of person-years retained during the study by encounter (i.e., years "in care" between cohort entry and final encounter) is different by region within every stratum (χ^2 test, $p < .05$).
* Age at cohort enrollment.
^a At the first measurement in each calendar year during follow-up.
^b At the last measurement in each calendar year during follow-up.
Region information missing for residents of Puerto Rico (N = 235), the US Virgin Islands (5), or where state-level residence was missing (N = 15).
Covariates: MSM: male sexual contact with men; IDU: injection drug use; History: heterosexual contact; ART: antiretroviral therapy; <3 agents: less than 3 classes or a single NRTI regimen containing abacavir or tenofovir.
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Table 1. Percent of person-years successfully retained (with % person-years contributed) in the NA-ACCORD, defined by encounters, by demographic, clinical, and geographic characteristics, from 2000 through 2010.
<http://dx.doi.org/10.1371/journal.pone.0146119.t001>

The percentage of individuals successfully retained increased from 2000 to 2010 in each region: from 73% (5,000/6,871; 7,189/8,462) in the Northeast, 75% (1,778/2,356) to 87% (1,630/1,880) in the Midwest, 68% (8,451/12,417) to 80% (9,147/7,520) in the South, and 68% (5,147/7,520) to 72% (6,401/8,895) in the West (Fig 1).

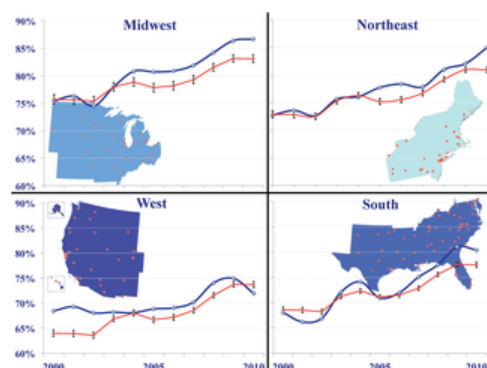


Fig 1. Temporal trends in percentage of individuals successfully clinically retained in the NA-ACCORD by CDC-defined region of the United States, from 2000–2010, by CDC-defined region of the United States.

Diamonds are National HIV/AIDS Strategy/Institute of Medicine retention indicator percentages (≥ 2 visits in a calendar year). Circles are Predictive Margins for the Probability of Being Retained by IOM indicator using a Region interaction effect (Fully Adjusted Logistic Model with GEE) U.S. Centers for Disease Control and Prevention (CDC)-c Regions: *Northeast*: CT, ME, MA, NH, NJ, NY, PA, RI, VT; *Midwest*: IL, IN, IA, KS, MI, MN, MO, NE, ND, OH, SD, WI, AL, AR, DE, DC, FL, GA, KY, LA, MD, MS, NC, OK, SC, TN, TX, VA, WV; *West*: AK, AZ, CA, CO, HI, ID, MT, NV, NM, UT, WA, WY.

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In adjusted regression models, there was a trend for improved retention over time ($p < 0.01$) for all regions. Over the study period, the probability of retention was lower in the West (Risk Ratio (RR): 0.94; 95% Confidence Interval (CI): 0.92–0.95) and the South (RR: 0.94; 95% CI: 0.93–0.95), and no different in the Midwest (RR: 1.02; 95% CI: 1.00–1.05), compared to the Northeast ($p < 0.01$). Other factors including younger age, male sex, Black race, and IDU and Heterosexual contact as HIV acquisition risk factors were significantly associated with a decreased likelihood of retention (Fig 2).

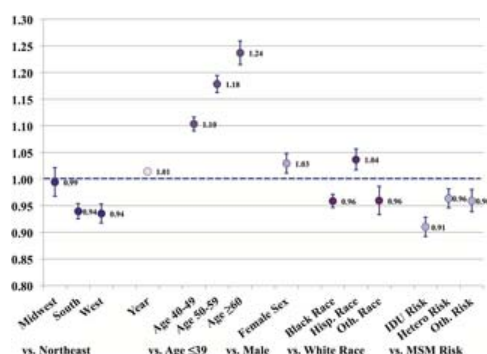


Fig 2. Risk Ratio estimates and 95% Confidence Intervals for factors associated with retention.

Results from modified Poisson regression model using a Generalized Estimating Equation and adjusting for total time in care.

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We found significant effect modification for racial differences in retention by region, in which the risk of retention among patients was poorer relative to White patients in the South than in other regions (RR: 0.94; 95% CI: 0.93–0.96, for Black patients in the South vs. the Northeast). We also found significant associations of baseline CD4+ count with retention within each region (Northeast, South, and West). However, the association in the Northeast (RR: 1.03 for both 200–349 and for ≥ 500 vs. < 200 cells/ μ L; $p = 0.02$ each) was in the opposite direction of the relationship in the South and West (higher baseline CD4+ count was associated with between 3 and 6% decreased probability of retention vs. < 200 cells/ μ L; $p \leq 0.01$ each, Table A in S1 File). Further, receipt of ART at baseline was associated with between 22 and 30% increased probability of retention within each region ($p < 0.01$ each, Table A in S1 File). In each of these secondary analyses, the magnitude, direction, and significance of the associations between

group, sex, race, HIV risk factor, geographic region and retention were similar to those in the primary analysis (data not shown). Though state-level patterns generally conformed to the regional patterns observed (Southern and Western states lagged observed and predicted retention probabilities over time), adjusting for state in the full model did not improve the model considerably. (Part F of Fig A in S1 File).

In models at the ZCTA-level, only an increase in median age (Odds Ratio (OR): 1.10 per year; 95% CI: 1.09–1.11) and in the census-based proportion of a ZCTA that were of Black race (OR: 0.36 per percentage difference increase from the proportion; 95% CI: 0.15–0.87) were significantly associated with improved retention (Table 2).

	Full Model	Model 2	Model 3	Model 4
QIC (Adjusted)	8724.7	8724.7	8722.8	8722.5
Median Age (Years)	1.10	1.10	1.10	1.10
Sample Proportion Female Sex	0.70	0.70	0.70	0.70
Sample Proportion Black Race	0.36	0.36	0.36	0.36
Sample Proportion CD4+ Ratio	0.99	0.99	0.99	0.99
Census Proportion Female Sex	0.99	0.99	0.99	0.99
Census Proportion Black Race	0.36	0.36	0.36	0.36
Census Proportion Rural Area	0.99	0.99	0.99	0.99
Census Proportion Living Below Poverty Line	0.99	0.99	0.99	0.99
Region				
Northeast	Reference	Reference	Reference	Reference
Midwest	0.99	0.99	0.99	0.99
South	0.99	0.99	0.99	0.99
West	0.99	0.99	0.99	0.99

Table 2. Estimated 95% Odds Ratios CIs for retention from ZCTA-level regression models.
<http://dx.doi.org/10.1371/journal.pone.0146119.t002>

Discussion

We found that among PLWHA successfully linked to and enrolled in care, the percentage of patients who were retained improved over time for all regions, with 72–87% retained in care in 2010. Despite this finding, the South and West exhibit retention levels over time compared to the Northeast. The results regarding the South are of particular concern in that they are troublingly consistent with surveillance and prior studies showing worse HIV outcomes, and significant sex and race differences in these outcomes, compared to the rest of the U.S.[17,19–22]. In the South, with its history of poorer educational performance, access to healthcare than much of the rest of the country, and regressive policies with respect to racial/ethnic and sexual orientation, the lag in improved quality of care outcomes could be the product of several forces.[17,18,21]. A geographically dispersed population with residents of more rural areas who have longer commutes to clinic locations in primarily urban centers could affect retention outcomes. Social stressors and structural factors that may limit the ability of individuals to access care (e.g., poverty, housing instability, discrimination, etc.) may also play an outsized role in the observed disparity of care between the South and Northeast, as noted in prior work.[21]. However, further research will be required to explore the role of these factors in clinical care in the population.

Despite regional disparities, however, the improvement in retention adds further evidence to earlier research that shows increasing percentages of large linked and clinically-engaged populations being retained over long periods of follow-up in the U.S.[39,45,48]. Notably, this upward trend persisted, even after adjusting for demographic, geographic, and HIV risk factor differences, and after accounting for differential contributions of time at risk for leaving care. This may have been due to attention to clinical retention during the study period or to increasing numbers of individuals placed on ART.[18,45]. Increased engagement between patient and providers. Examining retention patterns by CD4+ count at cohort entry, a non-delayed diagnosis or linkage to care, the South and West again exhibited decreased retention compared to the Northeast by similar magnitudes regardless of CD4+ stratum. This indicates that CD4+ count at entry to care did not significantly influence differences in retention over time between patients in the Northeast, South, and West, even though baseline CD4+ count improved between patients subsequently retained and not retained across the US.[38,39]. Though this appears to bode well for efforts to improve retention among all presenters for HIV care, it remains a powerful indication that even among patients linked to care in infection, there may remain structural factors that are region-specific which may dominate patients' subsequent experience in care.

Regarding ART use at cohort entry, an indicator of access to care, a fairly strong positive association between ART use and retention regardless of region may indicate the power of personal experience in engaging with healthcare services. This may include improved self-efficacy among patients and motivation to maintain contact with care providers once personally invested in their own medical care through ART use. However, it may also be the case that clinician decisions on initiating or continuing therapy favor patients more likely to improve their retention in care or those who have demonstrated stability in their clinical patterns (e.g., delaying ART initiation in IDU patients if they are actively using).[60]. This does contradict reports of wide clinician willingness to initiate therapy early in care among high risk patients, though in the largest such survey of clinicians the surveys were conducted only in New York and Washington, D.C.[61].

Many of the same groups that have been previously identified with suboptimal retention in care and inferior HIV outcomes in general, again emerged in this analysis. These groups include: younger individuals, Black patients, and those with IDU

factor.[29,32,62–64] Even though the unadjusted retention rates among these groups approaches the NHAS goal of 80 (Ryan White clients), there is room for improvement when compared to other HIV-infected sub-populations. Given those the fact that risk networks, culture, and socioeconomics may differ across regions, states, and more granular geographic identification of locales that may benefit most from interventions to improve healthcare quality, access, and retention remain important as ever. Clinicians and public health practitioners should note that though vulnerable and high burden groups again here may be obvious targets for interventions to improve access to and retention in care, their deficits may differ and a “one size fits all” approach at the national (and perhaps even the regional) level may not be warranted. It may even be the case that simply expanding the use of ART at entry to care may improve patient engagement and retention. Further analysis is required to isolate the potential effects of individual clinical decision-making before concluding that the observed relationship between ART use and retention is not due to confounding, though.

In this analysis, the regions analyzed were quite large, and economic, social, cultural, and political factors may vary widely within regions (e.g., the most and least populous US states, California and Wyoming, respectively, are in the same geographic region- the West). Because within-region and between-region differences may play significant roles influencing different retention and other HIV outcomes, the monitoring of geographic trends in HIV clinical care, including all stages of the care continuum, is an important activity to provide evidence for targeted outreach beyond a simple risk-group basis.

The additional analysis of ZCTA-level data, though providing a different lens through which to view demographic and HIV differences in retention in the US, add value in the additional layers of evidence they may provide to policy makers, particularly where individual-level data is unavailable.[65–67] Population-level differences in contextual factors such as poverty, crime, and social instability may also be a desirable focus for policy when considering aggregate characteristics separately from individual characteristics related to care at a more granular level than the state or region. In this case, the differences observed may stem from confounding by measured factors since the ZCTA-level analyses were adjusted using demographic and HIV characteristics, though they may be confounded by characteristics of the area of aggregation that were unavailable (such as housing and insurance income thresholds). Despite the limits in this context, these ZCTA-level analyses offer valuable insight into population-level processes such as persistent disparities in retention associated with regional age structure and racial composition that may be occurring in the care continuum at divisions smaller than the state level.

Scrutinizing outcomes at varying levels of geographic resolution is useful (and perhaps necessary) for detecting patterns that otherwise might be obscured.[68] Noting retention patterns across ZCTA, state, and region levels, our work found fairly consistent patterns though the quality of inferences may not necessarily reflect the level at which public health actions are likely to be taken. However, though the quality of inferences may not necessarily reflect the level at which public health actions are likely to be taken, effects may be most powerfully felt (Figs 3, 4 and 5). In the region-level map, the inter-regional disparities in retention are apparent while increasing levels of magnification present a more complicated picture with the patterns less discernable. However, in describing disparate HIV quality of care outcomes, it may be particularly powerful to depict trends across areas that have been noted to have somewhat distinct cultures, political structures, and epidemic profiles, as denoted by the disaggregation of data across these very same regions in national HIV surveillance reports.[49] The assessment and mapping of these outcomes across various levels, which is itself unusual, provides a compelling depiction of these HIV outcomes in a more easily accessible and readable format for both scientific and lay audiences.

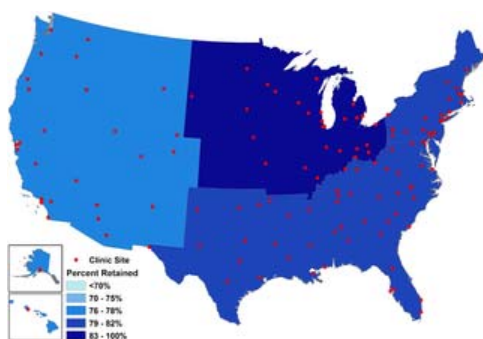


Fig 3. Region-level map of observed clinical retention status within the study sample in 2009 (N = 47,247), the final year in which all 11 cohorts contributed data.

<http://dx.doi.org/10.1371/journal.pone.0146119.g003>

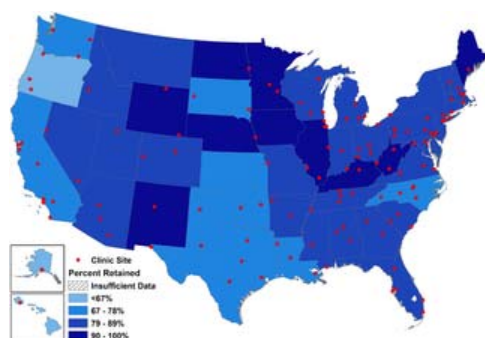


Fig 4. State-level map of observed clinical retention status within the study sample in 2009 (N = 47,247), the final year in which all 12 cohorts contributed data.

<http://dx.doi.org/10.1371/journal.pone.0146119.g004>

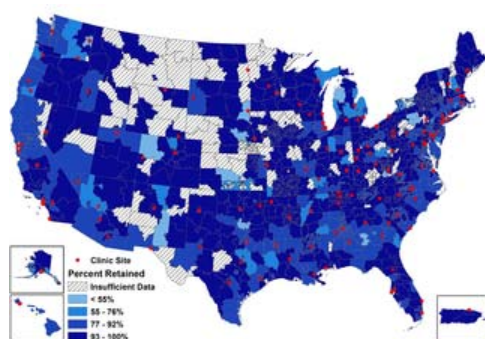


Fig 5. ZCTA-level map of observed clinical retention status within the study sample in 2009 (N = 47,247), the final year in which all 12 cohorts contributed data.

<http://dx.doi.org/10.1371/journal.pone.0146119.g005>

Further analysis incorporating smaller geographic divisions with richer individual- and population-level data (e.g., Medicare data at the individual-level) will be required to better understand how geographic factors, and the social-structural characteristics that are proxies of, impact retention in clinical care and HIV outcomes.

There were limitations in this analysis. First, medical insurance status and economic security are important factors influencing access to and retention in clinical care and which we did not have access to. We did, however, use census-derived proxy socioeconomic data such as the proportion of the ZCTA that was rural (indicating longer travel to receive care) and the proportion of the ZCTA living below the Federal poverty line (indicating economic and insurance resources available to patients). Since the group under observation was successfully linked to care and engaged at cohort enrollment, and therefore may not represent populations of greatest concern in the early stages of the continuum of care.

Using data from a large North American collaborative HIV cohort, our analysis demonstrated a persistent upward trend in care across the U.S., but one that was differential in its extent by region. These differences correspond with observed regional differences in other HIV outcomes and highlight the utility of geographic data and analyses in monitoring progress along the continuum of care on both a national and a local basis. Though policy prescriptions and public health actions such as expanding testing and prevention services or improved linkage and treatment programs may help stem the tide of the epidemic, more urgently needed in the South or the West, as opposed to the Northeast, is surely a critical piece of information.[69]

Supporting Information

S1 File.

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(PDF)

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Author Contributions

Conceived and designed the experiments: PFR SJG FCC. Performed the experiments: PFR. Analyzed the data: PFR. Wrote the paper: PFR SJG MAH AGA SN HS BR RDM MMK TRS FCC. Refined Methods and Interpretation of data: AGA SN BRY KNA FCC.

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