Early Retention in HIV Care and Viral Load Suppression: Implications for a Test and Treat Approach to HIV Prevention

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Background: After HIV diagnosis and linkage to care, achieving and sustaining viral load (VL) suppression has implications for patient outcomes and secondary HIV prevention. We evaluated factors associated with expeditious VL suppression and cumulative VL burden among patients establishing outpatient HIV care.

Methods: Patients initiating HIV medical care from January 2007 to October 2010 at the University of Alabama at Birmingham and University of Washington were included. Multivariable Cox proportional hazards and linear regression models were used to evaluate factors associated with time to VL suppression (<50 copies/mL) and cumulative VL burden, respectively. Viremia copy-years, a novel area under the longitudinal VL curve measure, was used to estimate 2-year cumulative VL burden from clinic enrollment.

Results: Among 676 patients, 63% achieved VL <50 copies per milliliter in a median 308 days. In multivariable analysis, patients with more time-updated "no show" visits experienced delayed VL suppression (hazard ratio = 0.84 per "no show" visit, 95% confidence interval = 0.76 to 0.92). In multivariable linear regression, visit nonadherence was independently associated with greater cumulative VL burden ($\log_{10}$ viremia copy-years) during the first 2 years in care (Beta coefficient = 0.11 per 10% visit nonadherence, 95% confidence interval = 0.04 to 0.17). Across increasing visit adherence categories, lower cumulative VL burden was observed (mean ± standard deviation $\log_{10}$ copy × years/mL); 0%–79% adherence: 4.6 ± 0.8; 80%–99% adherence: 4.3 ± 0.7; and 100% adherence: 4.1 ± 0.7 $\log_{10}$ copy × years/mL, respectively ($P < 0.01$).

Conclusions: Higher rates of early retention in HIV care are associated with achieving VL suppression and lower cumulative VL burden. These findings are germane for a test and treat approach to HIV prevention.

Key words: HIV, viral load, retention in care, adherence, engagement in care

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INTRODUCTION

In recent years, a test and treat approach to HIV prevention has garnered considerable interest. After HIV diagnosis ("test"), timely initiation and uninterrupted receipt of antiretroviral therapy (ART, "treat"), taken at a high level of adherence, can suppress plasma HIV viral load (VL) thereby significantly reducing the likelihood of transmission.[1–3] Implicit to the success of a test and treat strategy is the need for prompt linkage and sustained retention in HIV medical care after diagnosis. Currently, barriers exist at each step of the treatment cascade, from HIV testing and awareness of serostatus to VL suppression, that limit the effectiveness of test and treat in local communities and nationally.[4,5] An estimated 21% of HIV-infected individuals in the United States are unaware of their HIV serostatus and 31% of newly diagnosed persons delay linkage to outpatient HIV medical care for 6 months or longer.[6,7] Even with initial linkage into care, subsequent retention in HIV care is required for full access to treatment benefits. Early missed visits are common and have been associated with delayed initiation of ART in the short term and adverse clinical outcomes in the long term.[8,9] One-year attrition has been observed in upwards of 25%–30% of patients after initial enrollment in outpatient HIV care,

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compromising the potential real world impact of treatment as prevention strategies.[10,11]

Although numerous initiatives have focused on expanding HIV testing, and a brief case-management intervention has proven efficacious for linking newly diagnosed patients to care,[11,12] limited evidence, both observational and interventional, exists for the period immediately after entry to care.[9,10,13,14] The year after initial linkage to outpatient HIV medical care is a dynamic and formative time for patients adjusting to a life changing diagnosis. It is also a time of considerable vulnerability. Patients, many of whom have limited experience navigating the health care system and may not be fully prepared for a long-term commitment to taking prescribed medications, are called upon to attend frequently scheduled medical visits and initiate treatment with ART regimens that require high levels of sustained adherence to achieve success (eg, viral suppression) and avoid harm (eg, resistance mutations).[9,10] Suboptimal early retention in care represents a formidable obstacle to achieving HIV VL suppression, which has important individual and public health implications, yet little is known about its impact on the ultimate goal of test and treat strategies, viral suppression.

Here, we address this gap in the literature through the careful evaluation of the effect of early retention in HIV care on VL suppression. In addition to evaluating time to virologic suppression, we evaluate cumulative VL burden over the first 2 years in care. Beyond any single time point, longitudinal plasma viremia has important implications for patient outcomes and for HIV transmission. We use a novel measure, viremia copy-years, an area under the curve estimate of cumulative plasma VL exposure,[15] to characterize the relation between early retention in care and longitudinal VL burden. We hypothesized that early missed HIV care visits would be associated with delayed VL suppression, and that patients demonstrating poorer retention in care as measured by visit adherence would have higher cumulative viremia copy-years over the first 2 years of HIV care.

METHODS

Sample and Procedures

HIV-infected patients initiating outpatient HIV medical care at 2 academically affiliated HIV treatment centers at the University of Alabama at Birmingham (UAB 1917 Clinic) and the University of Washington (UW Harborview Clinic) between January 2007 and September 2010 were included in the overall study sample. Patients who had received outpatient HIV medical care at another facility before enrollment at the 2 study sites were excluded. To allow for a complete 2-year observation period, only the subset of patients initiating care before September 2008 were included in analyses of cumulative VL burden during the first 2 years after entry into outpatient HIV medical care. Data were captured through the Centers for AIDS Research Network of Integrated Clinical Systems (CNICS), a nationally distributed HIV clinical cohort that has been described in detail previously.[16] Briefly, every 2 months, sites transmit comprehensive and well-defined data elements captured from point-of-care electronic health record systems using standardized terminology and format. Systematic and rigorous processes for data verification and quality assurance are in place to generate a centralized high quality clinical database. This study and the CNICS protocol were approved by local institutional review boards at both study sites.

Outcome Measures: Plasma VL Suppression After Entry into Outpatient HIV Medical Care

Plasma HIV VL suppression after entry into care was evaluated using 2 distinct measures: time to suppression of plasma HIV RNA <50 copies per milliliter and cumulative VL burden measured over the 2 years after the initial medical visit. Viremia copy-years, a time-varying measure of cumulative plasma HIV burden calculated using methods described in detail previously, was used to evaluate longitudinal VL burden.[15] Briefly, the trapezoidal rule is used to approximate the integral representing the area under each patient's longitudinal VL curve. VL burden for each segment (time interval between 2 consecutive VL values) is calculated by multiplying the mean of the 2 values by the time interval. The copy × years per milliliter for each segment of a patient's VL curve are summed to calculate viremia copy-years. Formally, viremia copy-years is the number of copies of HIV RNA per milliliter of plasma over time. For example, 10,000 copy-years of viremia equals having a VL of 10,000 copies per milliliter for 1 year, or alternatively, a VL of 1000 copies per milliliter for 10 years. For the current study, viremia copy-years was calculated for each patient for 2 years starting from each patient's initial clinic visit date. Each patient's baseline VL was assigned to the initial medical visit date, and all VL values over the subsequent 2 years (730 days) were used in the viremia copy-years calculation (Fig. 1). Patients with a gap of >365 days between VL measures (n = 78) were excluded due to concerns about the reliability of calculating VL segments separated by long periods of time. Plasma VL values $>1{,}000{,}000$ copies per milliliter were administratively assigned a value of 1,000,000 copies per milliliter, and values below the limits of assay detection (49 copies/mL) were assigned a value of 24 copies per milliliter. Two-year viremia copy-years were calculated for all patients using natural non-transformed plasma HIV VL values. Subsequently, the 2-year viremia copy-year measure was $\log_{10}$ transformed for each patient. The 2-year $\log_{10}$ viremia copy-years measure was used for all analyses.

Principal Exposure of Interest: Early Retention in Care

Early retention in care was measured as a time-varying count of "no show" visits for time to VL suppression analyses (<50 copies/mL), and as visit adherence, the proportion of scheduled visits that were attended, for the evaluation of 2-year viremia copy-years.[17] Different measures were selected to best capture short-term and long-term retention in care in accordance with the outcome measures and analytic plan. During shorter observation periods fewer visits are available analytically, as observed for the time to VL suppression analyses (median = 5 visits, interquartile range = 3–9 visits), guiding our a priori selection of the "no show" count measure

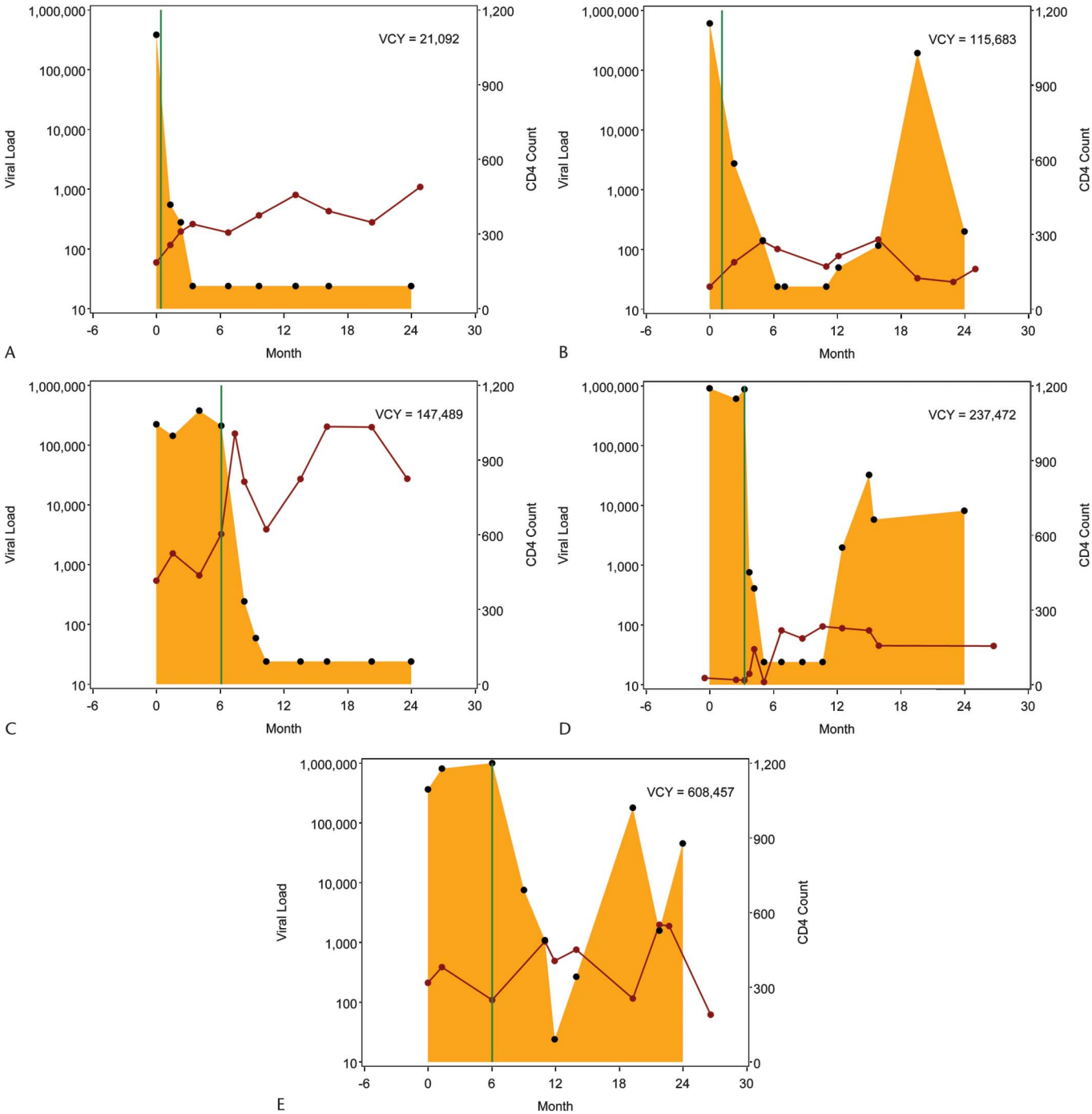

FIGURE 1. Example viremia copy-year plots depicting cumulative viral load burden over the first 2 years after initial entry to outpatient HIV medical care. Each black point represents a plasma viral load value, presented on a $\log_{10}$ scale, with the shaded area representing the area under the viral load curve, which is estimated by the viremia copy-years measure. The solid green line identifies the ART start date, and each red point represents a CD4+ T lymphocyte value, connected by a solid red line. A and B, Depict patients who started ART shortly after entering care at roughly the same viral load level who both achieved viral load suppression (<50 copies/mL) within 6 months of ART start. In contrast to patients of A, patients of B had viral load rebound after several suppressed viral load measurements resulting in accumulation of greater viremia copy-years. C–E, Depict patients who started ART after accruing several viral load measurements. Patients of C and D rapidly achieved viral load suppression (<50 copies/mL), with the former patient having sustained suppression whereas the latter had viral load rebound around month 12, after several suppressed values, with subsequent sustained detectable viremia resulting in greater viremia copy-years. Patient E achieved viral load suppression (<50 copies/mL) on one occasion, roughly 6 months after ART start, but had subsequent rebound, leading to considerably greater viremia copy-years than patients of C and D, who similarly achieved cross-sectional viral load suppression within 6 months of ART start.

for these analyses. Additionally, the "no show" count measure functions well as a time-varying covariate in survival analyses.[17] During the 2-year observation period for the cumulative viremia copy-years analyses, more HIV medical visits were scheduled (median = 10 visits, interquartile range = 8–16 visits), allowing a sufficient denominator to draw meaningful inference from the visit adherence measure. The visit adherence measure allows for more detailed evaluation of exposure–response relationships between retention in care and 2-year VL burden across a wider range (proportion bound by 0, 1) relative to the "no show" count measure and may be preferable for longer observation periods.[17] Only scheduled visits with a primary HIV medical care provider were included. In accordance with prior studies,[17–20] visits cancelled in advance by the patient and visits cancelled by the clinic and/or medical provider were excluded. In separate analyses, visit adherence was evaluated as a continuous measure and as a categorical variable; 0%–79%, 80%–99%, and 100% adherence, which roughly represented tertiles of the study sample.

Additional Covariates

Additional measures selected a priori included age, sex, race/ethnicity, health insurance, baseline CD4+ T-lymphocyte count, and baseline plasma HIV VL. Baseline plasma HIV VL and CD4+ T-lymphocyte count measurements were the value on the date nearest the initial medical visit date within a window of −180 to +7 days; median ± interquartile range of −3 (−23, 0) and −5 (−23, 0) days, respectively, from initial visit date.

Statistical Analyses

Descriptive statistics including means, standard deviations, medians, interquartile range, counts, and percents were calculated for all study variables as appropriate. Survival methods including Kaplan–Meier plots and Cox proportional hazards models were used to evaluate factors associated with time to first VL suppression (<50 copies/mL). Analysis of variance, linear regression, and analysis of covariance were used to evaluate factors associated with 2-year $\log_{10}$ viremia copy-years. All adjusted models controlled for covariates as outlined in the previous section. Sensitivity analyses included patients with a baseline CD4+T-lymphocyte count <350 cells per milliliter in accordance with the recommended threshold for ART initiation during the majority of the study period. Additional sensitivity analyses replaced the visit adherence measure with the "no show" count measure in the evaluation of 2-year viremia copy-years. All statistical analyses were performed using SAS version 9.2 (SAS Institute Inc, Cary, NC).

RESULTS

Among 676 patients, the mean ± standard deviation age at entry into care was 36 ± 11 years, 44% were non-white males, 13% were non-white females, 38% were white males, and 36% were uninsured (Table 1). The mean $\log_{10}$ baseline VL was 4.56 ± 0.97 $\log_{10}$ copies per milliliter, and 33% and 43% of patients had baseline CD4+ T-lymphocyte counts <200 cells per milliliter and >350 cells per milliliter, respectively. Twenty-five percent of patients had 2 or more no show visits, 79% initiated ART (median = 35 days from initial visit, interquartile range: 14–105 days), and 63% of the overall sample achieved VL suppression (<50 copies/mL) in a median 308 days (Kaplan–Meier estimate, interquartile range: 268–343 days) from entry into care. In adjusted Cox proportional hazards analysis, patients with private insurance [hazard ratio (HR) = 1.36 versus uninsured; 95% confidence interval (CI) = 1.08 to 1.73] and lower baseline CD4+ T-lymphocyte counts (<200 cells/mL: HR = 3.73; 95% CI = 2.82 to 4.93, and 200−350 cells/mL: HR = 2.96; CI = 2.26 to 3.86 versus >350 cells/mL) at entry into care experienced shorter times to VL suppression below 50 copies per milliliter (Table 2). Patients with higher baseline VLs (HR = 0.97 per additional 50,000 copies per milliliter; 95% CI = 0.96 to 0.99) and with more no show clinic visits (HR = 0.84 per additional no show visit; 95% CI = 0.76 to 0.92) experienced significantly longer time to VL suppression.

Two hundred fifty-eight patients with 2 years of follow-up from clinic entry were included in the evaluation of cumulative VL burden measured by viremia copy-years, as a function of early retention in care measured by visit adherence. In general, sociodemographic characteristics of these patients were comparable with the overall sample (Table 1). Over the first 2 years in outpatient HIV medical care, nearly half of patients (48%) had 2 or more no show clinic visits. The mean ± standard deviation visit adherence was 0.84 ± 0.16, and the following visit adherence categories were observed among patients: 0%–79% adherence in 83 patients (32%), 80%–99% adherence in 95 patients (37%), and 100% adherence in 80 patients (31%). Eighty-seven percent of patients started ART during the 2-year period, with 81% achieving a VL <50 copies per milliliter on at least 1 occasion. The mean ± standard deviation 2-year $\log_{10}$ viremia copy-years was 4.3 ± 0.8 copy x years per milliliter. Across increasing visit adherence categories, lower 2-year $\log_{10}$ viremia copy-years (mean ± standard deviation $\log_{10}$ copy × years/mL) was observed: 0%–79% adherence: 4.6 ± 0.8 (β = 0.47; 95% CI = 0.24 to 0.70), 80%–99% adherence: 4.3 ± 0.7 (β = 0.18; 95% CI = −0.04 to 0.40), and 100% adherence: 4.1 ± 0.7 $\log_{10}$ copy × years per milliliter (referent), respectively (Table 3). In multivariable linear regression, lower visit adherence (β = −0.11 per 10% visit adherence; 95% CI = −0.17 to −0.04) was associated with greater 2-year viremia copy-years.

Sensitivity analyses restricted to patients with baseline CD4+ T-lymphocyte counts <350 cells per milliliter on clinic entry (n = 372) yielded comparable findings to primary analyses. Ninety-seven percent of patients (n = 361) started ART with 76% (n = 283) achieving a VL <50 copies per milliliter in a median 192 days (Kaplan–Meier estimate, interquartile range: 175–211 days) from entry to care. In adjusted Cox proportional hazards analysis, patients with more no show clinic visits (HR = 0.81 per additional no show visit; 95% CI = 0.71 to 0.92) experienced significantly delayed time to VL suppression. As observed in primary analyses, visit adherence demonstrated an inverse relationship with 2-year $\log_{10}$ viremia copy-years in multivariable linear regression (β = −0.14 per 10% visit adherence; 95% CI = −0.19 to

TABLE 1. Characteristics of 676 HIV-Infected Patients Initiating Outpatient HIV Medical Care at the UAB 1917 and UW Harborview Clinics, January 2007 to September 2010

Characteristic	Overall Sample (n = 676)	Patients With 2 Years Follow-Up (n = 258)
Age (yrs)	35.8 ± 10.8	37.1 ± 10.3
Sex × race/ethnicity		
Non-white female	88 (13.3%)	31 (12.2%)
Non-white male	289 (43.7%)	109 (42.9%)
White female	31 (4.7%)	15 (5.9%)
White male	253 (38.3%)	99 (39.0%)
Health insurance		
Private	245 (37.6%)	96 (39.8%)
Public	174 (26.7%)	62 (25.7%)
Uninsured	232 (35.6%)	83 (34.4%)
Site		
UAB 1917 Clinic	417 (61.7%)	147 (57.0%)
UW Harborview Clinic	259 (38.3%)	111 (43.0%)
Baseline plasma HIV RNA (log_{10} copies/mL)	4.56 (0.97)	4.72 (0.94)
Baseline CD4+ T-lymphocyte count (cells/mL)	337 ± 255	334 ± 250
<200 cells/mL	215 (32.8%)	81 (32.4%)
200–350 cells/mL	158 (24.1%)	65 (26.0%)
>350 cells/mL	282 (43.1%)	104 (41.6%)
"No show" visits		
Zero	362 (53.6%)	80 (31.0%)
One	145 (21.5%)	53 (20.5%)
≥Two	169 (25.0%)	125 (48.4%)
Initiate ART	536 (79.3%)	224 (86.8%)
Achieve plasma HIV RNA <50 c/mL	425 (62.9%)	208 (80.6%)
2-year visit adherence	N/A	0.84 ± 0.16
0%–79%		83 (32.2%)
80%–99%		95 (36.8%)
100%		80 (31.0%)
2-Year viremia copy-years (log_{10} copy × years/mL)	N/A	4.31 ± 0.76

Data are presented as mean ± standard deviation or frequency (column percent).

Baseline plasma HIV RNA and CD4+ T-lymphocyte count measurements were the value on the date nearest the initial clinic visit date within a window of −180 to +7 days; median ± interquartile range of −3 (−23, 0) and −5 (−23, 0) days, respectively, from initial visit date.

"No show" visits: for the overall sample this represents a count with patients censored at first of plasma HIV RNA <50 copies/mL or administrative censoring; for the patients with 2 years follow-up (n = 258), this represents a count of no show visits during the first 2 years from clinic entry.

Missing data for overall sample and patients with 2 years follow-up: race/ethnicity (n = 15, 4), health insurance (n = 25, 17), baseline CD4+ T-lymphocyte count (n = 21, 8), respectively.

UAB, University of Alabama at Birmingham; UWUniversity of Washington.

−0.08). Finally, when replacing the visit adherence measure of early retention in care with the "no show" count measure, a comparable relationship was observed with greater 2-year log_{10} viremia copy-years among patients with more missed visits ($\beta = 0.11$ per "no show" visit; 95% CI = 0.08 to 0.14).

DISCUSSION

Early retention in HIV care was associated with time to VL suppression (<50 copies/mL) and 2-year cumulative VL burden among patients newly initiating outpatient HIV medical care. Each "no show" clinic visit conveyed a 17% increased risk of delayed VL suppression. Significantly greater viremia copy-years, an estimate of cumulative HIV burden, were accumulated among patients with poorer visit adherence over the first 2-years in care (4.6 ± 0.7 vs. 4.1 ± 0.8 log_{10} copy × years per milliliter for 0%–79% vs. 100% visit adherence). These findings have implications for patient outcomes, as recent studies have identified increased risk of deleterious clinical events among patients experiencing greater cumulative VL burden over time.[21,22]

Beyond individual health consequences, these findings have implications for HIV prevention efforts, particularly in the context of a test and treat approach to HIV prevention.[1,2,5] Failure to achieve and sustain VL suppression poses increased risk of HIV transmissibility.[3,23] In the current study, we identified poor early retention in HIV care as a barrier to timely VL suppression and a factor associated with greater cumulative VL burden over the first 2 years after entry into care. A recent study by Metsch et al identified reductions in sexual risk transmission behaviors among recently diagnosed patients with better early retention in HIV care relative to patients who were poorly retained.[24] Taken together, these 2 studies highlight the vital role of early retention in HIV care as it relates to sexual risk behavior and VL suppression—critical elements in secondary HIV

TABLE 2. Factors Associated With More Expeditious Suppression of Plasma HIV RNA (<50 copies/mL) Among 676 HIV-Infected Patients Initiating Outpatient HIV Medical Care at the UAB 1917 and UW Harborview Clinics, January 2007 to October 2010

Characteristic	Unadjusted HR (95% CI)	Adjusted HR (95% CI)
Age (per 10 years)	1.01 (0.92 to 1.10)	0.92 (0.84 to 1.02)
Sex × race/ethnicity		
Non-white female	0.82 (0.58 to 1.14)	0.76 (0.53 to 1.09)
Non-white male	1.24 (1.01 to 1.53)*	1.10 (0.88 to 1.37)
White female	0.73 (0.44 to 1.20)	0.91 (0.55 to 1.52)
White male	1.0	1.0
Health insurance		
Private	1.28 (1.02 to 1.61)*	1.36 (1.08 to 1.73)†
Public	1.09 (0.84 to 1.40)	1.17 (0.88 to 1.56)
Uninsured	1.0	1.0
Baseline plasma HIV RNA (per 50,000 c/mL)	1.01 (1.00 to 1.03)	0.97 (0.96 to 0.99)†
Baseline CD4+ T-lymphocyte count (cells/mL)		
<200 cells/mL	2.97 (2.35 to 3.76)†	3.73 (2.82 to 4.93)†
200–350 cells/mL	2.73 (2.12 to 3.50)†	2.96 (2.26 to 3.86)†
>350 cells/mL	1.0	1.0
"No show" visits (per additional "no show")	0.91 (0.84 to 0.98)*	0.84 (0.76 to 0.92)†

Unadjusted and adjusted Cox proportional hazards models. Adjusted model controls for variables included in the table and study site.
"No show" = count of no show visits as a time-varying covariate.
*$P < 0.05$.
†$P < 0.01$.

transmission, making early retention in care an important target for prevention interventions.

Previously, we identified significant independent associations between viremia copy-years and clinical outcomes among HIV-infected patients. Among Multicenter AIDS Cohort Study HIV-uninfected participants who seroconverted, viremia copy-years was associated with AIDS-defining clinical events and mortality in the precombination ART era (1984–1996).[15] Among CNICS patients initiating modern ART regimens (nonnucleoside reverse transcriptase inhibitor–based or protease inhibitor/ritonavir-based regimens) in recent years (2000–2008), viremia copy-years was independently associated with all-cause mortality when controlling for traditional cross-sectional VL measures and time-updated CD4+ T-lymphocyte count.[25]

Here, we extend the use of this novel, area under the curve estimate of cumulative VL burden by evaluating viremia copy-years as an outcome variable for the first time. Beyond single cross-sectional measures of VL suppression, we posit longitudinal measures of cumulative viremia may better predict individual risk of HIV transmission and may augment the evaluation of treatment as prevention interventions, the success of which is predicated on not merely achieving, but subsequently sustaining VL suppression. Moreover, we suggest viremia copy-years should be explored as a population-level indicator of transmission risk compared to single-measure indicators, such as community VL or the cross-sectional proportion of patients suppressed at the most recent measure or other single time point.

Our study has limitations. As with all observational studies, we can identify associations but not ascribe causality because our findings are subject to possible uncontrolled confounding. Patients had variable numbers and timing of VL measures, reflecting the realities of HIV clinical care. This may impact the precision of the viremia copy-years estimate of cumulative HIV burden. Patients with >365 days between VL measures were excluded to address this limitation. Although conducted at 2 sites in distinct regions of the United States, study findings may not be generalizable to other regions or settings. Future studies are planned to evaluate the generalizabilty of these findings to the larger nationally distributed CNICS cohort (8 sites). In this initial analysis, we did not formally evaluate the timing of ART receipt, ART persistence (or durability), and ART adherence in multivariable analyses, as these factors are on the causal pathway between early retention in care and VL suppression.[4,10] Here we sought to first establish the relationship between early retention in outpatient HIV care and VL outcomes. However, in exploratory analyses, the relationship between the number of "no show" visits and VL suppression persisted after controlling for initiation of ART as a dichotomous time-varying covariate (data not shown). Future studies using methods of causal inference (eg, structural equation models or marginal structural models) are planned to evaluate the intricacies of the dynamic relationships among variables on the causal pathway from entry to HIV care to longitudinal VL suppression, including early retention in care, initial ART receipt, ART persistency, and ART adherence. Finally, we did not systematically capture substance abuse, mental illness, and other psychosocial factors at care initiation such that we could not evaluate the role of these important and prevalent factors on early retention in care and VL suppression.

In conclusion, we identified significant associations between early retention in care and VL suppression among patients initiating outpatient HIV medical care. Beyond delayed time to VL suppression (<50 copies/mL) among

TABLE 3. Factors Associated With 2-Year Viremia Copy-Years, an Area Under the Curve Estimate of Cumulative Plasma HIV RNA Exposure, Among 258 HIV-Infected Patients Initiating Outpatient HIV Medical Care at the UAB 1917 and UW Harborview Clinics, January 2007 to October 2008

Characteristic	2-Year Viremia Copy-Years (Least Squares Mean ± 95% CI $\log_{10}$ Copy × Years/mL)	Unadjusted Beta-Coefficient (β) (95% CI)	Adjusted Beta-Coefficient (β) (95% CI)
Age (per 10 years)	N/A	−0.02 (−0.11 to 0.07)	0.04 (−0.06 to 0.13)
Sex × race/ethnicity			
Non-white female	4.01 (3.74 to 4.28)	−0.33 (−0.64 to −0.02)*	−0.06 (−0.37 to 0.25)
Non-white male	4.37 (4.22 to 4.51)	0.03 (−0.18 to 0.24)	0.13 (−0.08 to 0.34)
White female	4.36 (3.97 to 4.74)	0.02 (−0.39 to 0.43)	0.10 (−0.29 to 0.49)
White male	4.34 (4.19 to 4.49)	Referent	Referent
Health insurance			
Private	4.13 (3.98 to 4.27)	−0.23 (−0.44 to −0.01)*	−0.05 (−0.27 to 0.17)
Public	4.51 (4.33 to 4.69)	0.16 (−0.09 to 0.40)	−0.08 (−0.33 to 0.18)
Uninsured	4.35 (4.20 to 4.51)	Referent	Referent
Baseline CD4+ T-lymphocyte count (cells/mL)			
<200 cells/mL	4.30 (4.13 to 4.46)	−0.03 (−0.25 to 0.19)	−0.02 (−0.24 to 0.21)
200–350 cells/mL	4.23 (4.04 to 4.41)	−0.10 (−0.34 to 0.13)	−0.16 (−0.40 to 0.08)
>350 cells/mL	4.33 (4.18 to 4.48)	Referent	Referent
Visit adherence (β per 10%)	—	−0.11 (−0.17 to −0.06)†	−0.11 (−0.17 to −0.04)†
0%–79%	4.56 (4.40 to 4.72)	0.47 (0.24 to 0.70)†	—
80%–99%	4.27 (4.12 to 4.42)	0.18 (−0.04 to 0.40)	—
100%	4.09 (3.93 to 4.26)	Referent	—

Unadjusted and adjusted linear regression models. Adjusted model controls for variables included in the table and study site with visit adherence as a continuous variable (β-coefficient per additional 10% visit adherence).

*$P < 0.05$.

†$P < 0.01$.

patients with more "no show" visits, we demonstrated the importance of early visit adherence as it relates to cumulative HIV burden, measured by viremia copy-years. Longitudinal measures of cumulative VL burden, like viremia copy-years, may significantly contribute to the evaluation of test and treat HIV prevention interventions, the success of which are predicated on both rapidly achieving, and also longitudinally sustaining VL suppression.

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