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Informing targeted interventions to optimize the cascade of HIV care using cluster analyses of health resource use among people living with HIV/AIDS

Emanuel Krebs¹, Jeong E. Min¹, Ahmed Bayoumi⁵, Rolando Barrios^{1,4}, Julio S.G. Montaner^{1,2}, and Bohdan Nosyk^{1,3} on behalf of the STOP HIV/AIDS Study Group

¹BC Centre for Excellence in HIV/AIDS; Vancouver, British Columbia, Canada

²Division of AIDS, Faculty of Medicine, University of British Columbia; Vancouver, British Columbia, Canada

³Faculty of Health Sciences, Simon Fraser University; Burnaby, British Columbia, Canada

⁴Vancouver Coastal Health; Vancouver, British Columbia, Canada

⁵Department of Medicine, University of Toronto; Toronto, Ontario, Canada

Abstract

Increased awareness of the secondary preventive benefits of antiretroviral treatment (ART) has strengthened the desire to optimize health care systems' response to HIV/AIDS. We identified clusters of health resource utilization (HRU) among people living with HIV (PLHIV) to inform targeted interventions aimed to optimize the cascade of HIV care. Using linked population-level health databases in British Columbia, Canada, we selected two analytic samples of PLHIV with three years of follow-up between 2006–2011 that were classified as intermittently retained in care or intermittently engaged in ART, and executed a probabilistic model-based clustering analysis for each sample with 5 and 9 quarterly HRU variables, respectively. We found clear HRU profile differences among both samples with similar HIV-related care: one featured active involvement in non-HIV care, the other little or no health care interaction following linkage to care. Differential reengagement intervention strategies capitalizing on missed opportunities in non-HIV care and further engaging physicians delivering HIV care are needed to optimize the response to the HIV epidemic.

Keywords

HIV care; HIV interventions; targeted interventions; health resource utilization; clustering analysis; health administrative data

Corresponding Author: Bohdan Nosyk, BC Centre for Excellence in HIV/AIDS, St. Paul's Hospital, 613-1081 Burrard St., Vancouver, BC, Canada V6Z 1Y6, bnosyk@cfeenet.ubc.ca, T: 604-806-8649.

Compliance with Ethical Standards

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INTRODUCTION

Increased awareness of the secondary preventive benefits of antiretroviral treatment (ART) has strengthened the desire to optimize health care systems (1, 2). Immediate access to ART can provide important individual- and population-level benefits (3–5); however, these benefits rely on continuous lifelong ART engagement. The control of the human immunodeficiency virus (HIV) epidemic therefore hinges on health care systems maintaining continuous care to people living with HIV (PLHIV) (2, 6, 7).

The cascade of HIV care is a simple population-level framework tracking numbers of individuals living with HIV, diagnosed, retained in care, on ART and virally suppressed in a given jurisdiction (8). As a result, the cascade of HIV care identifies attrition along the HIV care continuum, emphasizing that maximizing sustained viral suppression among PLHIV requires a multi-faceted strategy to simultaneously improve testing, retention in care and sustained ART engagement. Recent modeling efforts by Skarbinski et al. (9) illustrate the critical need to improve retention: their findings suggest that while individuals diagnosed but not retained in care represent 45.2% of the population living with HIV, they are the source of 61.3% of new infections in the United States. Moreover, ART persistence, or sustained engagement captured by uninterrupted medication dispensation (as opposed to adherence, which measures doses ingested), is also critical, as the ultimate goal of sustained viral suppression cannot be achieved without it (10, 11).

Individuals lost to HIV care are a heterogeneous group composed of those never accessing a given level of care (12), those characterized by a longitudinal process of engagement, disengagement and reengagement in ART (13), as well as those completely disengaged from the health care system. While there have been substantial efforts to improve testing and linkage to care, there is sparse evidence on effective interventions to improve intermittent engagement in care or ART persistence (2, 7) and a recent systematic review failed to find a single evidence-based intervention designed specifically for reengagement in care (14). Understanding intermittent interactions with HIV care among PLHIV by identifying homogeneous health resource utilization (HRU) clusters, or subgroups, will be important for informing targeted reengagement interventions to optimize health care delivery systems (6, 15–19).

The cascade of HIV care provides a data-driven decision-making framework; expanding access to health administrative data can further enhance the evidence base needed to inform the public health response to the HIV epidemic. Linked administrative health data for British Columbia provides a unique opportunity as it features a single-payer health insurance system with comprehensive coverage of all medical care for PLHIV. We take advantage of comprehensive linked administrative health data captured for the population of PLHIV in British Columbia (BC) between September 1st, 2006 and March 31st, 2011 to empirically identify and characterize clusters of HRU among individuals with intermittent engagement in care and intermittent ART persistence in order to identify opportunities for re-engagement in HIV care.

METHODS

Study population

This study was based on a population-based linkage of seven health administrative databases and disease registries in British Columbia (BC), Canada. Data included physician billing records (Medical Services Plan database), hospitalizations (Discharge Abstract Database), non-antiretroviral drug dispensations (BC PharmaNet database), antiretroviral dispensations, plasma viral load (pVL) and CD4 tests (BC Centre for Excellence in HIV/AIDS drug treatment program and virology registries), HIV diagnosis (BC Centre for Disease Control HIV database) and mortality (BC Vital statistics database). Further details regarding the construction and composition of the comprehensive HIV-positive cohort and available databases are provided elsewhere (20, 21).

Within this cohort, we considered all individuals age ≥ 18 that were linked to care (defined as having a CD4 test after receiving a confirmation of HIV infection) from 1 September, 2006 to 31 March, 2011 with three years of follow-up (defined as having health administrative records from any of the linked databases and no record of death within three years) after linkage to care. Consequently, the most recent data included in the analyses were from 2014. As our goal was to identify HIV care reengagement opportunities, we selected two analytic samples of individuals classified as (a) intermittently retained in care, and (b) intermittently ART persistent during the three years following linkage to care. Therefore, we excluded from the intermittently retained in care analytic sample individuals that were either always or never retained in care, and from the intermittently ART persistent analytic sample those that were either always or never ART persistent.

We defined a validated time-dependent indicator of retention in care(8) that was updated on a quarterly basis and used it to classify individuals in the three mutually exclusive categories: (i) always retained in care; (ii) never retained in care; and (iii) intermittently retained in care. Retention in care was defined as having HIV-related care either as physician visits or diagnostic tests (CD4 cell count or pVL test) ≥ 3 months apart in the previous 12 months from the end of the quarter or at least two antiretroviral drug dispensations ≥ 3 months apart in the previous 12 months from the end of the quarter. Likewise, a validated time-dependent indicator of ART persistence (8) that was updated quarterly was used to classify individuals in the three mutually exclusive categories for ART persistence: (i) continuously ART persistent; (ii) never on ART; and (iii) intermittently ART persistent. ART persistence was defined as having no interruptions, defined as a gap of ≥ 30 days in administrative medication dispensation records, in the previous 12 months from the end of the quarter, or from the point of antiretroviral initiation for those who began treatment within the past 12 months. Further details regarding the construction of the indicators are provided elsewhere (8, 13). We chose a quarterly timeframe to mirror recommended CD4 and pVL monitoring guidelines, as per the International Antiviral Society–USA (IAS-USA) guidelines (22).

The study cohort was followed in a unique environment where medical care (HIV and non-HIV related), ART, and laboratory monitoring are fully subsidized by the BC provincial government. Antiretroviral drugs are centrally distributed according to provincial treatment

guidelines, which have remained consistent with those put forward by the International AIDS Society–USA (22, 23). Antiretroviral medication and viral load data captured in the BC Centre for Excellence in HIV/AIDS registries are complete for the provincial population of people living with HIV. The CD4 cell count data captured for this population have previously been estimated at 80% (24). This study received approval from the University of British Columbia/Providence Health Care Research Ethics Board.

Measures

We considered quarterly categorical HRU measures to be used for the clustering analyses and included variables that were not used in the selection of our analytic samples (Table 1). Cluster analysis for the intermittently retained in care was performed on five quarterly variables: one measure of non-HIV prescription medication days and four non-HIV-related care variables, including general practitioner (GP) visits, specialist visits, elective hospitalizations and hospital admissions through the emergency department (ED). In addition to these five measures, four equivalent HIV-related care variables were used for the cluster analysis of the intermittently ART persistent analytic sample. HIV-related care was defined using ICD9 or ICD10 codes where HIV was described as the condition or diagnosis being most responsible for the medical care received, or if there was more than one condition, where HIV was described as responsible for the greatest portion of the medical care received.

In order to characterize the clusters we hypothesized finding in our analyses, we incorporated a range of variables shown to impact retention in HIV care (7, 25) including individual demographics (age at linkage, gender, known HIV risk group status – men who have sex with men (MSM), history of injection drug use, mental health condition diagnosis), and HIV disease history at linkage to HIV care (time from diagnosis, CD4 and pVL tests, AIDS status). Finally, individual-level HRU costs, including physician billings, hospital admissions and medication dispensations, were derived using methods described elsewhere (26) and presented in 2016 Canadian dollars.

Statistical Analysis

Our statistical analysis proceeded in four steps. First, we computed summary statistics for the quarterly HRU measures of all individuals considered. Second, we assessed baseline demographic characteristics of all individuals that we considered for classification and we compared the characteristics of those who were selected to be included in our analytic samples, i.e. those classified as intermittently retained in care or intermittently ART persistent, and those who were not included in our analytic samples. Categorical variables were compared using Pearson's χ^2 tests, and continuous variables were compared using Mann-Whitney tests.

Third, we performed probabilistic model-based clustering analysis utilizing finite mixture densities with the quarterly categorical HRU variables described above. Five and nine variables defined for the twelve quarters following linkage to care were used for the intermittently retained in care sample and for the intermittently ART persistent sample, respectively. The goal was to partition individuals from each analytic sample into

clusters with similar HRU profiles so that individuals assigned to the same cluster were more similar to each other than those from a different cluster. Variables with no variation across individuals within a quarter were non-informative for clustering and were excluded from the analysis. Clustering with the use of finite mixture densities as models assumes the sample data is generated by a mixture of underlying population probability distributions. We used models appropriate for categorical data where the HRU variables were modeled within the mixture components by multinomial distributions (27). Model parameters were estimated by maximum likelihood (ML) using the expectation maximization (EM) algorithm, and given the estimators of the finite mixture density parameters, cluster membership was assigned by maximizing the posterior probability that an observation had been generated by a given cluster-specific mixture. Each observation can thus have an estimated posterior probability (EPP) of membership >0 for any cluster, and the maximum EPP determines cluster membership assignment. We considered models with two to eight clusters, with the optimal number of clusters established using the Bayesian Information Criterion (BIC) (28, 29). In order to find a good approximation to the global optimum, we minimized the BIC over 100 runs using randomly-selected starting values for model parameters. We then assessed the replicability of the cluster analysis solution for each analytical sample based on the stability of cluster membership assignment over 30 runs of the model with the optimal number of clusters, again selecting starting values randomly. Individuals were assigned final cluster membership based on the modal cluster membership assignment.

Finally, we assessed differences between clusters in three different ways. First, using variables that were used to generate the cluster solutions, we characterized quarterly HRU intensity using cluster median values. Second, we assessed individual-level differences in characteristics based on cluster membership using variables external to the cluster analyses. Finally, we compared average non-ART HRU costs over the three-year follow-up period across clusters.

Statistical analyses were executed in R version 3.1.2., SAS version 9.3 and Stata version 13.1.

RESULTS

Among the 1,078 individuals that met the study's inclusion criteria, the median age at time of linkage to care was 40, 23.1% were women, 36.5% identified as MSM and 32.7% were injection drug users (IDU). The analytic samples for the intermittently retained in care and intermittently ART persistent were respectively composed of 189 (17.5%) and 333 (30.9%) individuals, with 40 (3.7%) individuals included in both analytic samples (Figure 1).

Compared to individuals always retained in care, the intermittently retained in care had higher proportions of women (27.0% vs. 21.0%) and IDU (45.5% vs. 30.9%) but a lower proportion of MSM (27.0% vs. 41.9%). Similarly, the intermittently ART persistent also featured more women (29.7% vs. 13.5%), more IDU (44.7% vs. 22.1%) and less MSM (28.2% vs. 51.6%) when compared to individuals always ART persistent (Table 2).

Overall, six of the nine HRU variables available for use in the clustering analyses had quarterly median values equal to zero (Supplemental Table A1). The HRU variables with

less than 50% zero quarterly value observations were non-HIV GP visits (42.4%), non-HIV specialist visits (21.4%) and non-HIV prescription medication days (39.0%).

Model selection using the BIC favored two clusters for both analytic samples (Supplemental Table A2). The ratio of observations with an EPP of membership >0 to cluster size is indicative of how well the model can identify well-separated clusters(30), and a ratio of 1.0 would imply perfect separation. Among the intermittently retained in care, cluster 1 had 76 members (40.2%) with a ratio of 0.768 whereas cluster 2 had 113 members (59.8%) with a ratio of 0.926. The intermittently ART persistent clusters had 144 (43.2%) and 189 members (56.8%) with respective ratios of 0.837 and 0.892. Over the 30 repeated estimations, no cluster assignment switching among the intermittently retained in care or the intermittently ART persistent was observed.

Intermittently retained in care cluster characteristics

We found clear differences in HRU between clusters for the intermittently retained in care (Figure 2, top panel; Supplemental Table A3). The smaller cluster (cluster 1; N=76) was characterized by more frequent non-HIV GP visits and non-HIV specialist visits as well as more prescription medication days when compared to the larger cluster (cluster 2; N=113). Correspondingly, mean HRU costs over the follow-up period were greater for cluster 1 compared to cluster 2 (\$18,538 vs. \$6,066) (Supplemental Figure A1; Supplemental Table A4).

Furthermore, cluster 1 was composed of more IDU (63.2% vs. 33.6%), fewer MSM (13.2% vs. 36.3%) and had a higher prevalence of HRU related to mental health conditions (21.1% vs. 7.1%) when compared to cluster 2.

Intermittently ART persistent cluster characteristics

We also found clear differences in HRU between clusters for the intermittently ART persistent (Figure 2, bottom panel; Supplemental Table A5). Similarly, the smaller cluster (cluster 1; N=144) was characterized by more frequent non-HIV GP visits and higher numbers of prescription medication days compared to the larger cluster (cluster 2; N=189). However, the difference for non-HIV specialist visits among the intermittently ART persistent was less pronounced than it was among the intermittently retained in care. Likewise, mean HRU costs over the follow-up period were found to be greater for cluster 1 compared to cluster 2 (\$42,235 vs. \$10,394) (Supplemental Figure A1; Supplemental Table A4).

Otherwise, cluster 1 was made up of more IDU (71.5% vs. 24.3%) and more frequent HRU related to mental health conditions (26.4% vs. 5.3%) when compared to cluster 2. While initial CD4 test values did not differ across clusters for the intermittently ART persistent, the number of days between diagnosis and ART initiation was greater for cluster 1 (median: 146 days [IQR: 35, 354]) compared to cluster 2 (59 days [IQR: 13, 263]) (Table 3).

DISCUSSION

Using comprehensive population-level linked health administrative data, we found clear differences in HRU profiles among relatively homogeneous groups of PLHIV with respect to their HIV care interactions in a publicly-funded universal health care environment with centralized and free access to ART and HIV care. We identified two distinct clusters among both the intermittently retained in care and the intermittently ART persistent: one cluster was characterized by active involvement in non-HIV care while the other featured relatively little interaction with the health care system. Our findings suggest the need for differential reengagement intervention strategies to optimize the response to the HIV epidemic.

A novel finding to emerge from our analyses is that capitalizing on missed opportunities in non-HIV care offers a critical opportunity for improving continuous retention in HIV care. Routine HIV-related follow-up integrated across different clinical settings may provide an opportunity to prevent HIV care disengagement while providing PLHIV with better care management. In our context, our results of high prevalence of history of injection drug use among PLHIV intermittently engaged with HIV care but with frequent non-HIV care interactions resulted in a prescriber-focused intervention to increase HIV care engagement and retention outcomes among individuals engaged in treatment for opioid use disorder. The 'Expanded HIV care in opioid substitution treatment' (EHOST) study is a cluster-randomized, stepped-wedge trial encompassing all drug treatment clinics currently admitting patients for the treatment of opioid use disorder across BC, and we will be evaluating the intervention effectiveness of improving HIV care engagement over a 24-month period (31). The first 6-month period will be used for baseline measurement of HIV care delivered in drug treatment clinics and the intervention delivery for the first random cluster of clinics took place in the second 6-month period which started in September 2015. The intervention was developed through consultation with an advisory group of HIV care and addictions physicians, and entailed a scripted communication guide for the initial contact with the drug treatment clinic to determine support needs in scaling up HIV care, a consultation with an HIV specialist for the clinic's Medical Director, and an information package that provided posters, physician reminder cards and other HIV care resources to support physicians unfamiliar with HIV care. Opportunities to increase HIV care engagement and retention for patients could occur at three distinct times: (i) at the point of opioid use disorder treatment entry; (ii) following a period of non-adherence and (iii) at regular bi-annual intervals. Further details about the EHOST intervention can be found in the published study protocol (31). While not directly addressing challenges to access care associated with the high prevalence of mental health comorbidities among injection drug users (32), EHOST has nonetheless the potential to reduce HIV care fragmentation consequently providing critical opportunities for ART initiation and retention. Similarly, the need for strategies addressing barriers to HIV-care in substance use disorder treatment facilities in the United States has been emphasized in recent studies, including some showing low and sometimes declining rates of HIV testing and HIV-related care offered (33–36). Critically, rates of HIV-related care uptake were even lower, often despite the availability of free, on-site services (33, 35, 37).

Another opportunity to optimize health care delivery systems is to further engage physicians delivering HIV care, as underlined by our characterization of a cluster of individuals with no, or relatively little, interaction with the health care system, despite having already been linked to care following HIV diagnosis. As providers of HIV care may often be the only contact these individuals have with the health care system, offering enhanced care management tailored to these individuals may be an opportunity for improving retention in care. For instance, our ongoing evaluation of ‘Re-engagement and Engagement in Treatment for Antiretroviral Interrupted and Naive populations’ (RETAIN), a two-part province-wide intervention delivered by the BC Centre for Excellence in HIV/AIDS. First, alerts are automatically delivered to the primary care providers most recently linked to the patients when they either fail to refill their ART prescriptions for more than 60 days after the expected refill date, or have a HIV plasma viral load that measures more than 1,000 copies/mL and do not have a record of ART initiation. Once they have received an alert, physicians have the opportunity to provide any available information on the circumstances of their patient’s treatment interruption or delayed initiation, and can also make attempts to reach their patient. Second, patients not engaged or reengaged within 60 days to 120 days after the initial alert has been sent to their primary care provider are subject of an active public health intervention aiming to improve reengagement in HIV care, including outreach and case management if applicable. As suggested by our findings, the need for public health support may be particularly critical for PLHIV with psychiatric comorbidity, and the outreach staff can provide tailored assistance to individuals requiring additional attention in order to improve access to care and treatment retention. While ART interruption alerts have been issued for many years in BC, the ART naïve alerts and the public health referrals commenced in April 2015 and July 2016, respectively. This example of close integration of health care and public health action resonates with a broader interpretation of ‘treatment’ highlighted in calls for better control of the HIV epidemic (7, 38–40). More specifically, addressing the complex needs of PLHIV struggling to remain engaged in care has been recognized as an important factor in reaching the United States’ updated National HIV/AIDS Strategy goals (41), which include the increased retention in care of at least 90% of those diagnosed with HIV infection (17). Promisingly, there has been recent evidence suggesting that offering enhanced personal contact or active case management to retain PLHIV in care can be cost-effective (42, 43); however, a recent systematic review of interventions to improve ART adherence demonstrated that effective interventions were modest and waned over time (44). Continued efforts to evaluate and enhance the effectiveness of interventions such as RETAIN will be critical to maintaining PLHIV in continuous care.

In order to establish an effective HIV response with long-term sustainability, there is an urgent need to be more efficient in the manner with which we allocate resources available for HIV care. This process can be facilitated by prioritizing targeted interventions informed by a better understanding of interactions between PLHIV and health care delivery systems. While public health surveillance systems have been recommended for measuring retention in care over time (39, 45), reengagement initiatives building on information provided by these systems have shown mixed results among individuals lost to care (46–49). For example, a recent Los Angeles County intervention enrolled 7% of individuals identified as lost to care

or never in care, successfully retaining 82% of them in care 12 months after enrollment (49). Comparatively, a Washington State re-linkage intervention showed statistically significant but modest effectiveness in re-engaging patients lost to care compared to re-linkage occurring without an intervention among a historical cohort comparator (46). Recent epidemiological and economic modeling of incomplete engagement in HIV care has shown that focusing resources toward retention and reengagement interventions might be the most cost-effective use of resources (18, 50), however, there have been few evaluated interventions (2, 7, 18, 51). The pressing need to effectively address poor continuous retention in HIV care has prompted stakeholders to recommend augmenting surveillance systems with health administrative data for improving HIV care (17, 52). The Louisiana Public Health Information Exchange developed to deliver real-time provider alerts for lost to care individuals serves an example (53). Our study has shown how health administrative data can be used to provide the right reengagement interventions to the right patients before long-term loss to care occurs thus improving the efficiency of health care delivery.

This study has some limitations. First, caution must be exercised in applying these findings to other settings given the characteristics of clients, the nature of the HIV epidemic in BC and healthcare delivery policies. The analytical approach, however, is readily applicable in other settings. Second, while the characterization of clusters of health resource use among individuals always retained in care or those completely disengaged from care may suggest different patterns of interaction with the health care system, our findings have nonetheless the potential to inform targeted reengagement strategies critical for improving retention of individuals with intermittent interactions with HIV care. Third, ART receipt relied on prescription refill data and was thus measured with a degree of error. Although administrative loss to follow-up was considered, it is possible, although unlikely, that individuals may have received ART dispensations out of province during periods considered as treatment interruptions. Lastly, outpatient care from non-fee-for-service physicians practicing in community health centers as well as HIV-related care potentially delivered when physicians used non-HIV billing codes for their services were not captured in our administrative data, which in combination with our relatively small analytical samples may have obscured other heterogeneities in HRU profiles. Nonetheless, our findings provide clear and actionable evidence to guide re-engagement opportunities for the population under study.

Our results demonstrate how augmenting surveillance systems with health administrative data can be leveraged as a critical source of evidence to inform policy and optimize health care delivery systems. These findings serve to further underline the need for differential and targeted interventions among PLHIV in order to achieve continuous retention in HIV care, bolster the effects of ART, and ultimately control the HIV epidemic.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Appendix

The STOP HIV/AIDS Study Group is comprised of the following:

Rolando Barrios, Vancouver Coastal Health Authority
Patty Daly, Vancouver Coastal Health Authority
Reka Gustafson, Vancouver Coastal Health Authority
Perry RW Kendall, Provincial Health Officer
Gina McGowan, British Columbia Ministry of Health
Irene Day, BC Centre for Excellence in HIV/AIDS
Kate Heath, BC Centre for Excellence in HIV/AIDS
Robert S Hogg, BC Centre for Excellence in HIV/AIDS
Julio SG Montaner, BC Centre for Excellence in HIV/AIDS
Bohdan Nosyk, BC Centre for Excellence in HIV/AIDS

Figure 1.
Flow diagram for our study population selection process.

Figure 2.

Quarterly median health resource utilization, by cluster, for both the intermittently retained in care sample and for the intermittently ART persistent sample. GP: General practitioner; Elective: Elective hospitalizations; ED: Hospital admissions through the emergency department; Prescription: Prescription medication days.

Table 1Description of categorical quarterly health resource utilization variables used for clustering.[†]

<i>Intermittently retained in care</i>	<u>HIV-related</u>	<u>Non-HIV-related</u>
No. of GP visits	n/a	0, 1–3, 4–6, 7+
No. of Specialists visits	n/a	0, 1–3, 4–6, 7+
No. of Emergency Department visits	n/a	0, 1+
No. of Elective Hospital visits	n/a	0, 1+
No. of Prescription medication days	n/a	0, 1–90, 91–270, 271+
<i>Intermittently ART persistent</i>	<u>HIV-related</u>	<u>Non-HIV-related</u>
No. of GP visits	0, 1, 2, 3+	0, 1–3, 4–6, 7+
No. of Specialists visits	0, 1, 2+	0, 1–3, 4–6, 7+
No. of Emergency Department visits	0, 1+	0, 1+
No. of Elective Hospital visits	0, 1+	0, 1+
No. of Prescription medication days	n/a	0, 1–90, 91–270, 271+

[†] Quarterly categories were derived based on variable distributions. Non-HIV-related GP and specialists visits categories correspond to none, up to once monthly, once-to-twice monthly, and more than twice monthly. Prescription medication days correspond to none, up to one daily, one-to-three daily, and more than three daily.

No.: Number; ART: antiretroviral treatment; GP: General practitioner

Table 2

Individual descriptive characteristics, by longitudinal HIV care interaction classification.

	Retained in care			ART persistent		
	P-value		P-value	P-value		P-value
	Always	Never	Intermittently	Always	Never	Intermittently
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Patients	690 (64.0)	199 (18.5)	189 (17.5)	430 (39.9)	315 (29.2)	333 (30.9)
Female gender	145 (21.0)	53 (26.6)	51 (27.0)	58 (13.5)	92 (29.2)	99 (29.7)
Age: <30	138 (20.0)	39 (19.6)	57 (30.2)	82 (19.1)	92 (29.2)	60 (18.0)
30–40	216 (31.3)	54 (27.1)	53 (28.0)	126 (29.3)	88 (27.9)	109 (32.7)
40–50	212 (30.7)	62 (31.2)	60 (31.7)	125 (29.1)	88 (27.9)	121 (36.3)
50–60	96 (13.9)	28 (14.1)	13 (6.9)	76 (17.7)	28 (8.9)	33 (9.9)
>60	28 (4.1)	16 (8.0)	6 (3.2)	21 (4.9)	19 (6.0)	10 (3.0)
MSM *	289 (41.9)	53 (26.6)	51 (27.0)	222 (51.6)	77 (24.4)	94 (28.2)
Heterosexual *	230 (33.3)	43 (21.6)	49 (25.9)	120 (27.9)	69 (21.9)	133 (39.9)
Other *	37 (5.4)	6 (3.0)	8 (4.2)	20 (4.7)	10 (3.2)	21 (6.3)
Injection drug use	213 (30.9)	53 (26.6)	86 (45.5)	95 (22.1)	108 (34.3)	149 (44.7)
Hepatitis C co-infection	193 (28.0)	36 (18.1)	72 (38.1)	87 (20.2)	67 (21.3)	147 (44.1)
Mental health condition in year prior	74 (10.7)	23 (11.6)	24 (12.7)	37 (8.6)	36 (11.4)	48 (14.4)
AIDS-defining illness [§] in year prior	40 (5.8)	8 (4.0)	4 (2.1)	27 (6.3)	2 (0.6)	23 (6.9)
Time to linkage [Median (IQR)]	39 [16,105]	56 [35,116]	49 [28,162]	37 [16,80]	56 [28,257]	42 [23,90]
Delayed linkage (>90 days)	178 (25.8)	61 (30.7)	65 (34.4)	98 (22.8)	126 (40.0)	80 (24.0)
Time to ART initiation [Median (IQR)]	170 [38,585]	7 [0,416]	1046 [620,1348]	150 [29,608]	1387 [1247,1568]	96 [18,310]
First CD4 value [†] [Median (IQR)]	320 [180,500]	380 [240,570]	440 [310,580]	320 [180,490]	545 [430,735]	270 [168,410]
Number of CD4 tests [Median (IQR)]	14 [8,19]	3 [0,14]	4 [1,7]	14 [10,19]	2 [0,5]	12 [7,18]
Number of pVL tests [Median (IQR)]	14 [11,18]	9 [1,14]	6 [3,9]	14 [12,19]	5 [1,9]	13 [10,17]

Bold indicates analytic samples; Retained in care was defined as having either HIV-related physician visits or diagnostic tests (CD4 cell count or pVL test) 3 months apart within the past 12 months including the current quarter or at least two antiretroviral drug dispensations 3 months apart within the past 12 months including the current quarter; ART persistent was defined as having no interruptions, defined as a gap of 30 days between days in which medication was prescribed, within the past 12 months including the current quarter, or from the point of antiretroviral initiation for those who began treatment within the past 12 months; IQR: Interquartile range; pVL: plasma viral load

* Known characteristics (do not sum up to equivalent sample sizes)

Table 3

Individual descriptive characteristics, by cluster.

	Intermittently retained in care		Intermittently ART persistent		P-value
	Cluster #1	Cluster #2	Cluster #1	Cluster #2	
	N (%)	N (%)	N (%)	N (%)	
Individuals	76 (40.2)	113 (59.8)	144 (43.2)	189 (56.8)	
Female gender	22 (28.9)	29 (25.7)	52 (36.1)	47 (24.9)	0.026
Age: <30	19 (25.0)	38 (33.6)	26 (18.1)	34 (18.0)	0.080
30–40	20 (26.3)	33 (29.2)	39 (27.1)	70 (37.0)	
40–50	27 (35.5)	33 (29.2)	58 (40.3)	63 (33.3)	
>50	10 (13.2)	9 (8.0)	21 (14.6)	22 (11.6)	
MSM [*]	10 (13.2)	41 (36.3)	34 (23.6)	60 (31.7)	0.102
Heterosexual [*]	21 (27.6)	28 (24.8)	52 (36.1)	81 (42.9)	0.213
Injection drug use	48 (63.2)	38 (33.6)	103 (71.5)	46 (24.3)	<0001
Hepatitis C co-infection at linkage	39 (51.3)	33 (29.2)	98 (68.1)	49 (25.9)	<0001
Mental health condition in year prior	16 (21.1)	8 (7.1)	38 (26.4)	10 (5.3)	<0001
Time to linkage [Median (IQR)]	52 [25,190]	48 [28,154]	42 [25,113]	42 [21,85]	0.917
Delayed linkage (>90 days)	30 (39.5)	35 (31.0)	37 (25.7)	43 (22.8)	0.533
Time to ART initiation [Median (IQR)]	802 [426,1289]	1102 [713,1361]	146 [35,354]	59 [13,263]	0.001
First CD4 value [†] [Median (IQR)]	410 [310,610]	475 [290,580]	280 [130,420]	270 [170,380]	0.748

Retained in care was defined as having either HIV-related physician visits or diagnostic tests (CD4 cell count or pVL test) 3 months apart within the past 12 months including the current quarter or at least two antiretroviral drug dispensations 3 months apart within the past 12 months including the current quarter; ART persistent was defined as having no interruptions, defined as a gap of 30 days between days in which medication was prescribed, within the past 12 months including the current quarter, or from the point of antiretroviral initiation for those who began treatment within the past 12 months; IQR: Interquartile range; pVL: plasma viral load.

^{*} Known characteristics (do not sum up to equivalent sample sizes)

[§] As defined by World Health Organization

[†] cells/mm³