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Individual-Level and Clinic-Level Factors Associated With Achieving Glycemic Control in a Large Cohort of People With HIV in Care-Washington, DC

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Abstract

Background: Optimal management of noncommunicable diseases, including diabetes mellitus (DM), is crucially important as people with HIV (PWH) live longer with antiretroviral therapy. Our objective was to assess patient-level and clinic-level factors associated with achieving hemoglobin A1c (HbA1c) ≤7.0% among PWH and DM.

Setting: The DC Cohort, an observational clinical cohort of PWH, followed from 2011 to 2019 at 12 sites in Washington, DC.

Methods: Among PWH with diagnosed DM and elevated HbA1c (>7.0%), we examined the association between achieving HbA1c ≤7.0% and demographic and clinical factors, including time-updated medication data, and clinic-level factors related to services and structure. A multilevel marginal extended Cox regression model was generated to identify factors associated with time to HbA1c ≤7.0%.

Results: Over half (52.3%) of 419 participants achieved HbA1c ≤7.0%. Individual-level factors associated with HbA1c ≤7.0% included a diagnosis of DM after enrollment and a longer time since HIV diagnosis [hazard ratio (HR) = 2.65 and 1.13, $P < 0.05$ for both]. Attending a clinic with an endocrinologist was associated with the outcome [adjusted HR (aHR) = 1.41 95% confidence interval (CI): (1.01 to 1.97)]. In addition, comparing clinics that treat everyone, refer everyone or have a mix of treating and referring, showed an association between attending a clinic that treats

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everyone [aHR = 1.52 95% CI: (1.21 to 1.90)] or a clinic that refers everyone [aHR = 2.24 95% CI: (1.63 to 3.07)] compared with clinics with a mix in achieving glycemic control.

Conclusion: Multiple factors are associated with achieving glycemic control in an urban cohort of PWH. Determining if specific services or structures improve DM outcomes may improve health outcomes for PWH and DM.

Keywords

diabetes mellitus; glycemic control; HIV infection; clinic-level factors

INTRODUCTION

The availability of combination antiretroviral therapy (ART) has resulted in people with HIV (PWH) living longer[1] so much that the life expectancy of PWH is approaching that of the general population.[2–5] Multiple studies have shown ART medications are associated with PWH developing noncommunicable chronic diseases (NCDs), including type 2 diabetes mellitus (DM),[6–11] which is associated with shorter life expectancy[11] and a reported decline in quality of life.[12] The reported prevalence of DM among PWH in the United States varies from 5% to 19%.[7,10,13–17] The relationship between HIV and DM is essential because (1) DM is one of the major NCD that will account for the accelerated proportion of health care costs for PWH[18] and (2) both HIV and DM are independently associated with a higher risk of cardiovascular disease, one of the leading causes of mortality in PWH.[19]

In recent years, there has been a shift to recommend the inclusion of screening and coordinated treatment of multiple chronic comorbidities in HIV care.[20,21] Yet, many PWH are not being treated for their comorbid conditions where they seek care for HIV.[22] Although PWH often prefer to receive care where they get their HIV care,[20] many board-certified infectious disease (ID) physicians have reported feeling uncomfortable providing primary care for PWH.[23] Integration of general practitioners, nurse practitioners, and physician assistants into the HIV care centers to help provide care of non-HIV conditions could be one strategy to improve care for NCDs because it would reduce management responsibilities placed on the ID physician.[23]

Evaluating clinic treatment practices, including whether PWH with DM are meeting glycemic control targets, among clinics with different care management strategies for DM may provide additional knowledge on whether PWH with DM have better health outcomes if their HIV care provider treats them or if they are referred to care elsewhere. Clinic factors, such as having a clinical pharmacy on-site, the availability of diabetes education, weight loss management or smoking cessation programs at the clinic, and whether a patient is treated at the HIV clinic or is referred for diabetes care may also play a role in a patient's ability to achieve a specific DM treatment goal.

One management guideline for DM is to maintain a low target Hemoglobin A1c (HbA1c) level. The current guideline for PWH with DM is to achieve and sustain an HbA1c level less than 7%,[24] the same standard of care recommended to the general population of diabetes patients by the American Diabetes Association.[25] Studies have been conducted looking at

individual factors, such as age, viral suppression status, and DM medication usage, associated with achieving glycemic control among those with DM and HIV.[17,26–28] To the best of our knowledge, there is no published literature looking at the effect of clinic-level factors and services on glycemic control among PWH with DM, and only a few studies have assessed clinic-level factors in DM management in the general population.[29–31] In addition, all previous studies on assessing glycemic control in PWH with DM have been either cross-sectional studies assessed at a single time point[26,27] or repeated cross-sectional analyses.[17] So, there is no ability to adjust for any time-varying covariates, such as the type of DM medication used, which may affect a DM patient's ability to achieve glycemic control. The objective of this analysis was to evaluate what individual-level characteristics and clinic-level practices and services are associated with the achievement of DM control.

METHODS

Data Source

This analysis used data from the DC (District of Columbia) Cohort study. The DC Cohort is a longitudinal observational cohort of PWH receiving HIV care at one of 15 clinics in Washington, DC. The complete methods of DC Cohort have been described in previous publications.[32,33] Briefly, sociodemographic, clinical, and laboratory data documented in participants' outpatient electronic medical record (EMR) systems were abstracted into the DC Cohort database prospectively from the date of cohort enrollment. This analysis included data from 12 sites collected between January 2011 and March 2019.

In addition to the collected data from the EMR systems at each clinic, a site assessment survey of all DC Cohort sites was conducted in the first quarter of 2017. Site principal investigators received an electronic questionnaire that captured information about clinic characteristics, such as the types of providers, size of the clinic, and availability of an on-site pharmacy. In August 2019, the DC Cohort site principal investigators completed a supplementary survey specific to diabetes care within the HIV clinic. The complete list of variables generated from the original site assessment survey and diabetes care survey are listed in Table 1, Supplemental Digital Content, http://links.lww.com/QAI/B487. This protocol was approved by multiple institutional review boards, including the George Washington University.

Inclusion and Exclusion Criteria

Individuals were included in the analysis if they had a diagnosis of type 2 DM identified by *ICD-9/ICD-10* codes anytime during follow-up and had at least 1 year of follow-up time in the DC Cohort after the DM diagnosis was included in the database. In addition, the participant needed an initial HbA1c result above 7.0% and at least one subsequent HbA1c result anytime during follow-up to be included in the analysis. Individuals younger than 18 years at the time of consent and those enrolled at one of the 3 sites primarily providing HIV care for a pediatric or adolescent patient population were excluded from the analysis.

Outcome of Interest

The outcome of interest was the achievement of glycemic control, defined as having at least one subsequent HbA1c laboratory result test of 7.0% or below after the initial HbA1c result >7.0%. Achievement of glycemic control was assessed as a time-to-event outcome.

Individual-Level Covariates

Individual-level predictors were abstracted from the medical record at the time of the baseline HbA1c result unless otherwise stated. Individual-level predictors assessed for an association with glycemic control included sociodemographic characteristics (age, sex at birth, and race/ethnicity), body mass index, behavioral risk factors (known histories of smoking, alcohol abuse, recreational drug use, or intravenous (IV) drug use, each classified as ever or never at the time of enrollment), social factors (housing, employment status, and insurance status), diabetes-related factors, [baseline HbA1c value, whether the participant was diagnosed with DM before enrollment in the DC Cohort and DM medication usage, which were time-updated based on medication start and stop dates abstracted from prescription EMR data (see Table 2, Supplemental Digital Content, http://links.lww.com/QAI/B487 for the classification of DM medications)], HIV-related variables (primary mode of HIV transmission, having an AIDS defining condition, length of HIV diagnosis, nadir CD4 count, most recent CD4 count and HIV viral load, exposure to ART associated with DM, and current ART regimen, which were time-updated based on medication start and stop dates abstracted from prescription EMR data), and evidence of having other specified comorbid conditions (hypertension, dyslipidemia, hypothyroidism, chronic renal failure, chronic hepatitis C, anxiety or stress disorder, or depression).

Clinic-Level Covariates

A variety of clinic-level variables were considered related to clinic structure and self-management opportunities, including the size of the HIV patient population, whether the clinic has specific types of clinicians on staff (endocrinologists, nutritionists, nurse practitioners, and physicians assistants), whether the clinic has specific lifestyle modification programs (diabetes education, weight management, and smoking cessation), the presence of an on-site pharmacy or urgent care services, the standard DM screening interval at the clinic, and whether PWH are treated for DM in the HIV clinic, if the clinic both treats and refers PWH to other clinics within the same medical institution for DM treatment, or if the PWH are not treated for care in the HIV clinic (see Table 1, Supplemental Digital Content, http://links.lww.com/QAI/B487 for the survey questions and variables constructed with the responses).

Statistical Analysis

Descriptive statistics for the study sample were generated using χ^2 or Fisher exact tests for categorical variables and Wilcoxon rank sum tests for continuous variables. These descriptive statistics were stratified by whether or not participants achieved glycemic control. In addition, all static factors were evaluated with Kaplan–Meier curves and through goodness of fit testing, to confirm proportional hazards assumptions were met. To account for different lengths of follow-up time among participants and to allow variables with values

that change over the course of time, an extended Cox hazards regression[34] was performed to assess the individual-level and clinic-level factors associated with achieving an HbA1c level of ≤7%. This analysis was a marginal multilevel regression, allowing both individual-level and clinic-level factors to be assessed for an association with achieving glycemic control. Each individual-level covariate was evaluated in a univariate Cox regression model. Individual factors determined a priori (age, race/ethnicity, and sex at birth) and those found to be significantly associated with achieving glycemic control ($P < 0.05$) were included in the evaluation of clinic-level factors. Each clinic-level variable was evaluated separately, adjusting for the selected individual-level factors using marginal extended Cox regression with a robust sandwich covariance matrix to account for the intracluster effect of clinic site.[35,36] These results were evaluated by the empirical Wald test[37] for each clinic-level outcome separately, and those with a P value of less than 0.1 were assessed for inclusion in the final model. The final multilevel, multivariate marginal extended Cox regression model included all previously selected individual-level variables and clinic-level factors selected based on goodness of fit using likelihood-ratio testing[37] that were significantly associated with achieving glycemic control ($P < 0.05$). All analyses were performed in SAS (9.4).

RESULTS

Overall, the DC Cohort had 1624 PWH and DM among 10,124 participants (16.1%) at the 12 sites included in this analysis. The prevalence of DM among the 12 clinics ranged from 11.1% to 23.0%. Among all DC Cohort participants meeting the inclusion criteria, 419 had a diagnosis of DM. Of those, 219 participants (52.3%) achieved glycemic control with an HbA1c value of ≤7.0%. The median age of the overall sample (N = 419) was 54 years, and the sample was predominately men (66.3%) and non-Hispanic black (87.6%) (Table 1). Those who had lower baseline median HbA1c (8.0% vs. 9.3%; $P < 0.0001$), had been diagnosed with HIV for a longer duration (14.9 years vs. 12.3 years; $P = 0.01$), and did not have a DM diagnosis at the time of enrollment into the DC Cohort (70.3% vs. 89.0%; $P < 0.0001$) were more likely to achieve glycemic control (Table 1).

As shown in Table 2, all individual-level characteristics were assessed separately for an association with time to achievement of glycemic control. In unadjusted analysis, participants who had their first recorded diagnosis of DM at their HIV care site after consenting to the DC Cohort were more likely to achieve an HbA1c of ≤7.0% compared with those diagnosed before enrollment [hazard ratio (HR) = 2.65, 95% confidence interval (CI): (1.65 to 4.25)]. Those who had been living with HIV longer [HR = 1.13; 95% CI: (1.01 to 1.26) for every 5 years since diagnosis] were more likely to achieve glycemic control. The use of a noninsulin medication [HR = 1.52; 95% CI: (1.13 to 2.04)] and a history of recreational drug use [HR = 1.30; 95% CI: (1.06 to 1.60)] were significant predictors of glycemic control. Those with higher baseline HbA1c [HR = 0.78; 95% CI: (0.71 to 0.87) for every 1.0% increase in HbA1c] and those with hypertension [HR = 0.73; 95% CI: (0.56 to 0.95)] were less likely to achieve glycemic control.

Table 3 shows the unadjusted association between clinic-level variables and achieving HbA1c ≤7.0%. Attending a clinic with an endocrinologist on staff and having a smoking cessation program at the clinic were significantly associated with achieving glycemic control

[adjusted HR (aHR) = 1.45 and 1.34, $P < 0.05$ for both]. Clinics that did not refer patients to another clinic at the institution for DM management were more likely to achieve glycemic control [aHR = 1.77; 95% CI: (1.20 to 2.61)] as were those that did not treat DM but instead referred patients to another clinic within the medical institution [aHR = 1.61; 95% CI: (0.97 to 2.69)]. These aHRs were both in comparison to clinics that do not have a set clinical practice and may treat DM in the clinic or refer patients for DM care to another clinic in the institution.

The final multilevel multivariable model evaluating the association of reaching an HbA1c value of ≤7.0% revealed that both individual-level and clinic-level factors were associated with achieving glycemic control (Table 4). Significant individual-level factors were as follows: a recent diagnosis of DM [aHR = 2.43; 95% CI: (1.63 to 3.64)], use of only noninsulin medication(s) [aHR = 1.32; 95% CI: (1.01 to 1.73)], a history of using recreational drugs [aHR = 1.48; 95% CI: (1.13 to 1.94)], and living with HIV for a longer period of time [aHR = 1.13; 95% CI: (1.01 to 1.26)] for every 5 years since diagnosis). Participants with a higher initial HbA1c value [aHR = 0.83; 95% CI: (0.76 to 0.90) for every 1.0% increase in HbA1c] and a comorbid diagnosis of hypertension [aHR = 0.64; 95% CI: (0.51 to 0.80)] were less likely to achieve glycemic control.

Attending a clinic with an endocrinologist on staff [aHR = 1.41; 95% CI: (1.01 to 1.97)], having a smoking cessation program at the clinic [aHR = 1.33; 95% CI: (1.01 to 1.75)], offering urgent care services [aHR = 1.49; 95% CI: (1.04 to 2.13)], and the clinics that treat DM and do not refer participants to other clinics [aHR = 1.52; 95% CI: (1.21 to 1.90)], as well as the clinics who refer all participants for DM care and do not treat DM in the clinic [aHR = 2.24; 95% CI: (1.63 to 3.07)] were all the significant clinic-level variables in the final multilevel model associated with achieving glycemic control.

DISCUSSION

To the best of our knowledge, this is the first study to assess both the individual-level and clinic-level factors associated with achieving glycemic control in PWH with DM. After adjusting for individual-level factors including baseline HbA1c and type of DM medication, we found a variety of clinic-level factors associated with improved control, including having a clinic with an endocrinologist on staff, a site that offered a smoking cessation program, clinic providing urgent care services, and a clinic that either uniformly treats or uniformly refers patients for DM. This research provides evidence for the value of certain clinic-based services for assisting PWH with DM to achieve a target HbA1c value.

An important finding from this study was that 2 different DM management strategies were both associated with a faster time to achieving glycemic control. Participants were more likely to achieve glycemic control if the clinic either consistently treated DM within the HIV clinic or consistently referred participants to receive DM care in a different clinic within the health care institution, where participants at clinics that consistently referred out participants with DM had the highest rate of achieving glycemic control. This was in comparison to participants who attended HIV clinics where both treatment and/or referral for DM care occurred rather than a uniform approach. As PWH live longer and develop NCDs, many

HIV providers have begun to manage and treat NCDs in their patient population, whereas some providers still prefer to refer treatment for NCDs, such as DM, to specialists. Previous research focused on whether care for NCDs should occur within the HIV clinic or if PWH should be referred to a specialist for care.[21,23] However, more recent research has shifted focus to explore whether different models of care, such as the Patient-Centered Medical Home (PCMH)[38,39] or Chronic Care Model,[40] offer better care outcomes for PWH. These models have similar elements essential to optimizing care for patients, including patient-driven care, team-based management, and communication and coordination through clinical information systems, such as linked EMRs.[38–40] Although there is evidence showing a PCMH approach works to provide preventive and primary care for patients with multiple morbidities, including both DM[41–43] and HIV,[22,38,40,44] there is limited data to support which treatment model has the most significant benefit on patient outcomes for PWH with DM.[22,44]

There are several possible explanations for the clinic treatment/referral findings. Individuals who are treated within the HIV clinic for all their comorbidities are receiving care within the patient-driven paradigm of the PCMH. PWH have previously reported they prefer to be treated for other comorbid conditions in the HIV clinic rather than be referred to specialty care.[20,40,45] PWH who are receiving care for DM at their HIV clinic have direct coordinated care, where care for both conditions is being managed by the same provider or a team of providers working together to manage the patient's care needs, which has shown to result in better health outcomes, especially for DM care.[41,42] In addition, PWH and DM at clinics that refer out the care for DM were also more likely to achieve glycemic control in this analysis. Although this may seem contradictory, other researchers found the PCMH care model does not have to be specific to the clinic and can extend to the larger institution or even another outside institution if PCMH principles are implemented, primarily through the implementation of technology, such as a shared EMR and protocols for care coordination.[38] A clinic must be using an EMR platform for clinical record management to be a clinic site in the DC Cohort, and specific data points must be able to be extracted using a specified protocol.[32] All clinics in the DC Cohort that refer care for the treatment of DM are referring their patients to other clinics within the same hospital or medical center. All clinics within the same medical institution are using the same EMR platform, so all providers have access to the entire EMR record for a patient, regardless of which provider is seeing the patient. By staying within the same medical institution, it allows HIV clinicians and specialists for referred care to have access to laboratory results and medication information that might not be available if the patient was referred outside the institution. However, our surveys did not have any questions that addressed how or if communication and care coordination are performed. More research is needed to show how larger institutions and/or outside institutions can act as a PCMH or medical "neighborhood"[39] and what effect these have on achieving care outcomes in PWH with other comorbidities.

We also found that having an endocrinologist on staff at the HIV clinic and having urgent care services available at the clinic were associated with achieving glycemic control. Having a specialist on staff and having colocated urgent care both support the PCMH framework of patient-centered management by a multidisciplinary team, which has consistently been associated with achieving better care outcomes in PWH[38,39,44,46] and DM.[41–43,47] A

previous study looking at clinic-level factors associated with ART initiation and viral suppression also found that team-based care, such as having gynecology and psychiatry services, available were associated with a faster time to achievement of both outcomes of interest.[48] In addition, in the literature, ID physicians have reported feeling uncomfortable providing primary care for PWH and are 4 times more likely to refer their HIV patients for hypertension or diabetes care rather than treat them in the HIV clinic.[49,50] The use of a multidisciplinary team within the HIV clinic could reduce the number of referrals for care for comorbid conditions while not requiring the ID physicians to take the lead to manage these conditions. The promotion of a team-based approach provides a collaborative way to address provider concerns and improve health outcomes for PWH with additional comorbidities.

We acknowledge certain limitations of this study. The DC Cohort does not currently collect data on service utilization, so this analysis could only determine if a service or program was present but not if a patient was participating in the service. In addition, the DC Cohort also does not capture information on the treating physician, so when specialists are available at the clinic, we do not know if care for DM is conducted by an endocrinologist or the HIV provider. Future research looking at patient utilization of services and treating physician records could greatly enhance our knowledge on the impact of clinic-based resources on achieving glycemic control goals. In addition, there may be differences in the implementation of services between the clinics in the DC Cohort. The surveys did not collect details about the differences in services available at each clinic to capture commonalities available between the clinics, and the inclusion of too many correlated variables would have been problematic in creating the multilevel model due to the small number of clinic sites (n = 12) in this analysis.

To be included in this analysis, we required all participants to have a diagnosis of DM because it is hard to determine what factors are associated with achieving glycemic control if participants are unaware of their diabetic status. The Center for Disease Control has shown that an estimated 21.4% of diabetics in the United States are undiagnosed.[51] Therefore, the results of this analysis are only generalizable to all those PWH with a known diagnosis of DM. Because the DC Cohort is an observational study where all data are obtained from the patients' EMR at routine care visits, we only have data available when a participant attends the clinic. Therefore, those participants who have more frequent care visits contributed more data to the analysis, had more opportunities to be tested, and may have been more likely to achieve an HbA1c of 7%. In addition, almost 80% of the study population included in this analysis was diagnosed with DM before enrolling in the DC Cohort. As a result, those who had an HbA1c above 7% and have now achieved an HbA1c at or below 7% were not able to be included in this analysis. We also did not calculate the cumulative time a participant spent at or under an HbA1c level of 7% because of the inability to account for the time and HbA1c exposure before enrollment for most of the participants in the study. Future research investigating if there are any factors associated with greater time spent at desired HbA1c levels in this population be beneficial in helping clinicians treat DM in PWH. Another limitation is that the Cohort currently only captures EMR data and does not include pharmacy records. The study currently captures prescription records, so we were only able to capture data on the type of treatments prescribed and were not able to adjust for

medication adherence in the model. Lifestyle modifications, including physical activity and diet modification, have been shown to be highly associated with lowering HbA1c levels among people with diabetes[25]; however, the DC Cohort does not capture data on lifestyle modifications so these data could not be included in the analysis. These types of data could be incorporated using patient self-reported data which is a future goal/initiative of the Cohort. Clinicians have also begun to recommend personalized goals for glycemic control standards for patients with DM based on multiple factors, including "pharmacotherapy, patients' preferences, patients' general health and life expectancy, treatment burden, and costs of care."[52] We were unable to determine if patients in the DC Cohort were meeting personalized glycemic control targets, hence we used the current guideline of ≤7.0% for PWH with DM recommended by the HIV primary care guidelines.[24]

Despite these limitations, our study has many strengths. The use of a multilevel model allowed for the assessment of both clinic-level and individual-level covariates and their association with achieving an HbA1c level of ≤7%. The use of an extended Cox regression model was also strength of this analysis because it allowed us to account for different lengths of follow-up time among participants and use time-updated covariates in the analysis that would have violated the assumptions of a Cox proportional hazard model.

In conclusion, we found that multiple factors are associated with achieving glycemic control in an urban cohort of PWH. Identification of clinic-level services and practices associated with the achievement of glycemic control is needed to identify potential programs and standard services to be offered for people with HIV with DM. These findings emphasize the importance of incorporating treatment strategies for NCDs into care for PWH and that continued research on the impact of clinic-level resources and site management practices is necessary.

NH, non-Hispanic.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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TABLE 1.

Sociodemographic and Clinical Characteristics of Diabetic Participants With Initial HbA1c > 7.0% at the Start of Study Observation by Achievement of Glycemic Control Status, DC Cohort 2011–2019 (N = 419)

		Achieved HbA1c <7% (N = 219)	Did Not Achieve HbA1c <7% (N = 200)	
Individual-Level Characteristics	**Total Cohort (N = 419)**	**N (%)**	**N (%)**	***P***
Age, median (IQR)	54 (49–60)	55 (50–60)	54 (48–59)	0.14
Sex at birth				0.58
Male	278 (66.3%)	148 (67.6%)	130 (65.0%)	
Female	141 (33.7%)	71 (32.4%)	70 (35.0%)	
Race/ethnicity				0.37
NH black	367(87.6%)	194 (88.6%)	173 (86.5%)	
All other races	52 (12.4%)	25 (11.4%)	27 (13.5%)	
Body mass index				0.98
Normal weight (<25 kg/m^2)	64 (15.3%)	33 (15.1%)	31 (15.5%)	
Overweight (25–30 kg/m^2)	112 (26.7%)	60 (27.4%)	52 (26.0%)	
Obese (≥30 kg/m^2)	210 (50.1%)	108 (49.3%)	102 (51.0%)	
Insurance status *				0.10
Private	127 (30.3%)	60 (27.4%)	67 (33.5%)	
Public	281(67.1%)	157 (72.7%)	124 (62.0%)	
Employment status				0.27
Employed	99 (22.6%)	46 (21.0%)	53 (26.5%)	
Unemployed	126 (30.1%)	64 (29.2%)	62 (31.0%)	
Others/unknown	194 (46.3%)	109 (49.8%)	85 (42.5%)	
Housing status				0.26
Permanent	346 (82.6%)	177 (80.8%)	169 (84.5%)	
Unstable/homeless	34 (8.1%)	17 (7.8%)	17 (8.5%)	
Unknown	39 (9.3%)	25 (11.4%)	14 (7.0%)	
DM diagnosis at enrollment †	332 (79.2%)	154 (70.3%)	178 (89.0%)	**<0.0001**
Median initial HbA1c measurement (IQR)	8.5 (7.5–10.5)	8.0 (7.4–9.1)	9.3 (7.9–10.8)	**<0.0001**
Diabetes medication ‡				**0.03**
No medication	178 (42.5%)	101 (46.1%)	77 (38.5%)	

Individual-Level Characteristics	Total Cohort (N = 419)	Achieved HbA1c <7% (N = 219) N (%)	Did Not Achieve HbA1c <7% (N = 200) N (%)	*P*
Noninsulin medication only	131 (31.3%)	71 (32.4%)	60 (30.0%	
Insulin only	78 (18.6%)	29 (13.3%)	49 (24.5%)	
Both insulin and noninsulin medication	32 (7.6%)	18 (8.2%)	14 (7.0%)	
History of ART associated with DM[§]	132 (31.5%)	74 (33.8%)	58 (29.0%)	0.29
Median HIV duration in yr (IQR)	13.5 (7.3–18.1)	14.9 (8.9–20.0)	12.3 (6.3–17.4)	**0.01**
Transmission risk				0.59
MSM	108 (25.8%)	56 (25.6%)	52 (26.0%)	
IDU	46 (11.0%)	28 (12.8%)	18 (9.0%)	
Heterosexual	184 (43.9%)	96 (43.8%)	88 (44.0%)	
Others/unknown	81 (19.3%)	39 (17.8%)	42 (21.0%)	
AIDS diagnosis	205 (48.9%)	114 (52.1%)	91 (45.5%)	0.18
Using any ART[†]	371 (88.5%)	190 (86.8%)	181 (90.5%)	0.23
Use of a PI-based regimen[‡]	154 (36.8%)	82 (37.4%)	72 (36.0%)	0.76
Use of a NNRTI-based regimen[‡]	121 (28.9%)	62 (28.3%)	59 (29.5%)	0.79
Use of a INSTI-based regimen[‡]	168 (40.1%)	80 (36.5%)	88 (44.0%)	0.12
CD4 count (median, IQR)	583.5 (391.5, 848)	573(367, 834)	593 (414, 859)	0.36
Nadir CD4 count (median, IQR)	275 (102,428)	251 (103, 409)	294 (101.5, 462.5)	0.23
HIV viral load (median, IQR)	u (u, 40)	u (u, 32)	u (u, 40)	0.76
History of smoking at enrollment[†]	225 (53.7%)	122 (55.7%)	103 (51.5%)	0.39
History of alcohol abuse at enrollment[†]	109 (26.0%)	59 (26.9%)	50 (25.0%)	0.30
History of recreational drug use at enrollment[†]	133 (31.7%)	80 (36.5%)	53 (26.5%)	**0.03**
History of IV drug use at enrollment[†]	62 (14.8%)	39 (17.8%)	23 (11.5%)	0.07
Evidence of hypertension[//]	376 (89.7%)	191 (87.2%)	185 (92.5%)	0.08
Evidence of dyslipidemia[//]	255 (60.9%)	128 (58.5%)	127 (63.5%)	0.29
Evidence of hypothyroidism[¶]	17 (4.0%)	5 (2.3%)	12 (6.0%)	0.12
Evidence of chronic renal failure[¶]	99 (23.6%)	54 (24.66%)	45 (22.5%)	0.60
Evidence of chronic hepatitis C[#]	53 (12.7%)	32 (14.6%)	21 (10.5%)	0.21
Evidence of anxiety/stress disorder[#]	62 (14.8%)	35 (16.0%)	27 (13.5%)	0.47

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Individual-Level Characteristics	Total Cohort (N = 419)	Achieved HbA1c <7% (N = 219) N (%)	Did Not Achieve HbA1c <7% (N = 200) N (%)	*P*
Evidence of depression[¶]	103 (24.6%)	50 (22.8%)	53 (26.5%)	0.38

Bold indicates $P<0.05$.

[*] Public insurance includes Medicare, Medicaid, and other public insurances.

[†] Variable assessed at enrollment into the DC Cohort.

[‡] Variable was updated as it changed throughout the analysis. Table shows the initial values at the start of observation.

[§] Stavudine, zidovudine, didanosine, indinavir, or saquinavir. Previous use of these ART drugs obtained through a chart review of prescription records at enrollment.

[‖] Participants were defined as having the comorbidity if the participant met at least one of 3 criteria: (1) an *ICD-9* or *ICD-10 (International Classification of Diseases*, 9th or 10th Revision) code that indicated a diagnosis, (2) a drug prescription suggesting receipt of treatment, or (3) based on clinical or laboratory results indicating disease onset.

[¶] Participant was determined to have the condition if the participant either had an *ICD-9* or *ICD-10* code that indicated a diagnosis or based on clinical or laboratory results indicating disease onset.

[#] Participant was determined to have the condition if the participant either had an *ICD-9* or *ICD-10* code that indicated a diagnosis.

IDU, male or female injection drug user; INSTI, integrase strand transfer inhibitor; IQR, interquartile range; IV, intravenous; MSM, men who have sex with men; NH, non-Hispanic; NNRTI, nonnucleoside reverse transcriptase inhibitor; PI, protease inhibitor; PWH, people with HIV.

TABLE 2.

Individual-Level Factors Associated With Achieving Glycemic Control in PWH With DM With Initial HbA1c >7.0% Measurement at the Start of Study Observation, DC Cohort 2011–2019

	Unadjusted HR (95% CI)
Age (per 5 yrs)	1.05 (0.99 to 1.11)
Sex at birth (female vs. male)	0.88 (0.74 to 1.04)
Race/ethnicity (all other races vs. NH black)	0.95 (0.65 to 1.40)
BMI at start of observation	
Overweight (25–30 kg/m^2) vs. normal weight (<25 kg/m^2)	0.99 (0.53 to 1.86)
Obese (≥30 kg/m^2) vs. normal weight (<25 kg/m^2)	0.98 (0.60 to 1.60)
Insurance status (public/unknown vs. private)	0.97 (0.68 to 1.37)
Employment status (unemployed/unknown vs. employed)	1.15 (0.84 to 1.58)
Housing status (unstable/homeless vs. permanent)	1.14 (0.87 to 1.42)
DM diagnosis at enrollment (no vs. yes)	**2.65 (1.65 to 4.25)**
Initial HbA1c measurement (per 1%)	**0.78 (0.71 to 0.87)**
DM medication use	
Noninsulin medication only vs. no medication	**1.52 (1.13 to 2.04)**
Insulin only vs. no medication	0.76 (0.53 to 1.09)
Both insulin and noninsulin medication vs. no medication	0.98 (0.48 to 2.01)
History of ART associated with DM (yes vs. no)	1.04 (0.73 to 1.49)
Length of HIV duration in yr (per 5 yrs)	**1.13 (1.01 to 1.26)**
Transmission risk	
Heterosexual vs. MSM	0.86 (0.60 to 1.23)
IDU vs. MSM	1.11 (0.76 to 1.60)
Others/not reported vs. MSM	0.88 (0.64 to 1.21)
AIDS diagnosis at enrollment (yes vs. no)	1.21 (0.87 to 1.68)
Using any ART (no vs. yes)	0.96 (0.66 to 1.40)
Use of a PI (no vs. yes)	1.02 (0.76 to 1.38)
Use of a NNRTI (no vs. yes)	0.98 (0.85 to 1.14)
Use of a INSTI (no vs. yes)	1.12 (0.85 to 1.48)
CD4 count at start of observation (per 100 cells/mm^3)	0.98 (0.94 to 1.02)
Nadir CD4 count at start of observation (per 100 cells/mm^3)	0.97 (0.91 to 1.04)
Viral suppression (>200 copies/mL) at the start of observation (no vs. yes)	1.00 (0.68 to 1.48)
Known history of smoking (yes vs. no)	1.04 (0.78 to 1.36)
Known history of alcohol abuse (yes vs. no)	0.94 (0.64 to 1.39)
Known history of recreational drug use (yes vs. no)	**1.30 (1.06 to 1.60)**
Known history of IV drug use (yes vs. no)	1.34 (0.89 to 2.01)
Hypertension (yes vs. no)	**0.73 (0.56 to 0.95)**
Dyslipidemia (yes vs. no)	0.90 (0.70 to 1.14)
Hypothyroidism (yes vs. no)	0.72 (0.40 to 1.27)
Chronic hepatitis C (yes vs. no)	1.18 (0.84 to 1.66)
Chronic kidney disease (yes vs. no)	1.10 (0.87 to 1.39)

	Unadjusted HR (95% CI)
Anxiety/stress disorder (yes vs. no)	1.26 (0.91 to 1.75)
Depression (yes vs. no)	0.85 (0.69 to 1.04)

Diabetes medication use and ART medication use are time-updated based on evidence that a prescription was ended or a new prescription was prescribed.

Bold indicates $P<0.05$.

BMI, body mass index; IDU, male or female injection drug user; INSTI, integrase strand transfer inhibitor; MSM, men who have sex with men; NH, non-Hispanic; NNRTI, nonnucleoside reverse transcriptase inhibitor; PI, protease inhibitor; PWH, people with HIV.

TABLE 3.

Proportion of PWH With DM With Initial HbA1c >7.0% Measurement by Final Glycemic Control Status, Attending a Clinic With the Listed Clinic-Level Factor, and the Association* of Each Clinic-Level Factor With Glycemic Control Status, DC Cohort, 2011–2019

	Achieved HbA1c <7% (N = 219)	Did Not Achieve HbA1c <7% (N = 200)	
	N (%)	N (%)	Adjusted HR* (95% CI)
At a clinic with an endocrinologist on staff (yes vs. no)	161 (73.5%)	123 (61.5%)	**1.45 (1.03 to 2.04)**
Treatment for diabetes at the clinic			
Clinic treats most patients with DM at the HIV clinic but does refer some patients to another clinic within the institution	63 (28.8%)	78 (39.0%)	Ref
Clinic treats most patients with DM at the HIV clinic and does not refer patients to another clinic within the institution	67 (30.6%)	36 (19.5%)	**1.77 (1.20 to 2.61)**
Clinic does not treat most patients with DM at the HIV clinic but refers most patients to another clinic within the institution	89 (40.6%)	83 (41.5%)	1.61 (0.97 to 2.69)
At a clinic with a diabetes education program (yes vs. no)	133 (60.7%)	121 (60.5%)	1.33 (0.94 to 1.88)
At a clinic with a weight management program (yes vs. no)	120 (54.8%)	118 (59.0%)	1.23 (0.86 to 1.75)
At a clinic with a nutritionist on staff (yes vs. no)	128 (58.5%)	122 (61.0%)	1.24 (0.88 to 1.73)
At a clinic with a smoking cessation program (yes vs. no)	163 (74.4%)	142 (71.0%)	**1.34 (1.03 to 1.75)**
At a clinic with an on-site pharmacy (yes vs. no)	184 (84.0%)	139 (69.5%)	*1.60 (0.98 to 2.62)*
At a clinic with urgent care services (yes vs. no)	200 (91.3%)	155 (77.5%)	*1.99 (0.98 to 4.04)*‡
At a clinic with physician assistants on staff (yes vs. no)	73 (33.3%)	48 (24.0%)	1.15 (0.82 to 1.59)
At a clinic with nurse practitioners on staff (yes vs. no)	133 (60.7%)	111 (55.5%)	0.91 (0.58 to 1.43)
Size of HIV clinic (over 1000 patients vs. 1000 or less patients)	182 (83.1%)	153 (76.5%)	1.16 (0.80 to 1.69)

Bold indicates significant at the $P<0.05$ level.

Italic values indicates $P<0.1$.

* Each point estimate reported in this table is the aHR for the listed clinic-level variable included as the only clinic-level variable in a model adjusted for the following individual-level variables: age, race/ethnicity, sex at birth, baseline HbA1c value, diabetes diagnosis at enrollment into the DC Cohort, use of diabetic medications (time-updated), HIV duration, and diagnosis of hypertension at start of observation.

TABLE 4.

Final Multilevel Model of Individual-Level and Clinic-Level Factors Associated With Glycemic Control Status, DC Cohort, 2011–2019

	Adjusted HR (95% CI)*
Individual level	
Age (per 5 yrs)	1.04 (0.97 to 1.11)
Sex at birth (female vs. male)	1.08 (0.93 to 127)
Race/ethnicity (all other races vs. NH black)	0.80 (0.51 to 1.28)
DM diagnosis at enrollment (no vs. yes)	**2.43 (1.63 to 3.64)**
Initial HbA1c measurement (per 1%)	**0.83 (0.76 to 0.90)**
DM medication use	
Noninsulin medication only vs. no medication	**1.32 (1.01 to 1.73)**
Insulin only vs. no medication	1.13 (0.74 to 1.73)
Both insulin and noninsulin medication vs. no medication	1.35 (0.79 to 2.30)
Length of HIV duration in yr (per 5 yrs)	**1.13 (1.01 to 1.26)**
Known history of recreational drug use (yes vs. no)	**1.48 (1.13 to 1.94)**
Hypertension (yes vs. no)	**0.64 (0.51 to 0.80)**
Clinic level	
At a clinic with an endocrinologist on staff (yes vs. no)	**1.41 (1.01 to 1.97)**
Treatment for diabetes at the clinic	
Clinic treats most patients with DM at the HIV clinic but does refer some patients to another clinic within the institution	Ref
Clinic treats most patients with DM at the HIV clinic and does not refer patients to another clinic within the institution	**1.52 (1.21 to 1.90)**
Clinic does not treat most patients with DM at the HIV clinic but refers most patients to another clinic within the institution	**2.24 (1.63 to 3.07)**
At a clinic with a smoking cessation program (yes vs. no)	**1.33 (1.01 to 1.75)**
At a clinic with urgent care services (yes vs. no)	**1.49 (1.04 to 2.13)**

Each point estimate reported in this table is the aHR with all other individual-level and clinic-level factors included in the model.

Bold indicates $P<0.05$.

*The overall significance of the model had a P value of < 0.0001 based on the empirical Wald test.