Potential Impact of Integrating HIV Surveillance and Clinic Data on Retention-in-Care Estimates and Re-Engagement Efforts

Eva A. Enns, PhD, MS,¹ Cavan S. Reilly, PhD, MS,² Beth A. Virnig, PhD, MPH,¹
Karen Baker, MPH, MHI,³ Nicholas Vogenthaler, MD,⁴ and Keith Henry, MD⁴

Abstract

Retention in care is essential to the health of people living with HIV and also for their communities. We sought to quantify the value of integrating HIV surveillance data with clinical records for improving the accuracy of retention-in-care estimates and the efficiency of efforts to re-engage out-of-care patients. Electronic medical records (EMRs) of HIV+ patients ≥ 18 years old from a public, hospital-based clinic in Minneapolis, MN between 2008 and 2014 were merged with state surveillance data on HIV-related laboratory tests, out-of-state relocation, and mortality. We calculated levels of retention and estimated the number of required case investigations to re-engage patients who appeared to be out of care over the study period with and without surveillance data integration. Retention was measured as the proportion of years in compliance with Health Resources and Services Administration (HRSA) guidelines (two clinical encounters >90 days apart annually) and the proportion of patients experiencing a gap in care >12 months. With data integration, retention estimates improved from an average HRSA compliance of 70.3% using EMR data alone to 77.5% with surveillance data, whereas the proportion of patients experiencing a >12 -month gap in care decreased from 45.0% to 34.4%. If case investigations to re-engage patients were initiated after a 12-month gap in care, surveillance data would avoid 330 (29.3%) investigations over the study period. Surveillance data integration improves the accuracy of retention-in-care estimates and would avert a substantial number of unnecessary case investigations for patients who appear to be out of care but, in fact, receive care elsewhere or have died.

Introduction

RECOGNITION OF THE importance of regular engagement in medical care to the health of people living with HIV (PLWH) and their communities is highlighted in the updated National HIV/AIDS Strategy, which sets a goal of having 90% of all PLWH in the United States retained in care by 2020.¹ Inconsistent engagement in care is associated with as much as a twofold increase in mortality^{2–4} as well as with increased risks of viral rebound, treatment failure, and drug resistance.^{5–10} In contrast, those receiving regular medical care have greater access and adherence to antiretroviral therapy and are more likely to achieve viral suppression,^{11,12} which drastically reduces the risk of transmitting HIV to others.^{13–15}

However, the US Centers for Disease Control and Prevention (CDC) estimated that in 2012 only 53.8% of PLWH in the United States met the CDC's criteria for being engaged in care, having at least two viral load or CD4 count tests at least 3 months apart in the past 12 months.¹⁶

Although many states have programs to link newly diagnosed PLWH into care initially, once a patient has established care, the responsibility of retaining and re-engaging that patient in care largely falls to their HIV care provider. Clinic-based outreach efforts have been demonstrated to be effective at re-engaging patients who appear to be out of care in pilot programs, when those patients can be reached.^{17–19} However, one of the main challenges for such efforts is identifying which patients are truly out of care. A patient

Portions of this analysis will be presented at the 38th Annual Meeting of the Society for Medical Decision Making, October 23–24, 2016 and at the 144th Annual Meeting of the American Public Health Association, October 29–November 2, 2016.

Divisions of ¹Health Policy and Management and ²Biostatistics, University of Minnesota School of Public Health, Minneapolis, Minnesota.

³Analytic Center of Excellence and ⁴Division of Infectious Diseases, Hennepin County Medical Center, Minneapolis, Minnesota.

might appear to be out of care due to the long gap in time since their previous clinical encounter; however, providers are rarely informed when a patient receives care elsewhere, relocates, or dies, all of which could explain a patient's absence from the clinic.

Integration of HIV surveillance data with clinic data can improve the process of determining a patient's care status. Previous studies in specific clinics in Los Angeles, San Francisco, Seattle, and Chicago found that 45–52% of patients classified as “out of care” according to clinic medical records, in fact, had records of death, relocation, or evidence of care at another facility in state HIV surveillance databases.^{18–21} These findings highlight the importance of collaboration between healthcare providers and state health departments in patient re-engagement efforts. However, it is unclear whether these estimates hold for other geographic settings and to what extent ongoing integration of HIV surveillance data in a clinic's re-engagement activities would impact the amount of resources needed to manage case loads.

We sought to assess the impact of integrating clinic and HIV surveillance data on retention-in-care estimates in an urban Midwestern setting and to quantify the value of this data integration in better targeting outreach resources to those patients who are truly out of care. We analyzed data from a public, hospital-based HIV clinic in Minneapolis, Minnesota, combined with information from Minnesota's state HIV surveillance system. Minneapolis is a mid-sized Midwestern city in a state with low-to-moderate HIV incidence and prevalence.²²

Methods

This study was approved by the internal review boards of the University of Minnesota and the Minnesota Medical Research Foundation (on behalf of Hennepin County Medical Center).

Study population

The study population consisted of all adult HIV+ patients seen at least once between 2008 and 2013 by the Positive Care Clinic (PCC), a hospital-based HIV clinic located within the Hennepin County Medical Center in Minneapolis, MN. Patients must have been seen at least once by a prescribing physician (medical doctor or nurse practitioner) to be included. Patients younger than 18 years old at the first observed visit were excluded. The PCC is the largest provider of HIV care in Minnesota. In 2013, the clinic saw 1685 HIV+ patients, which represents 22% of all PLWH in Minnesota and 42% of PLWH living in the twin cities of Minneapolis and St. Paul.²³

Data sources

Electronic medical records (EMR) data from the PCC were extracted for all qualifying individuals from all clinic visits and HIV-related laboratory tests between January 1, 2008 and December 31, 2014. Demographic data were also extracted from the EMRs, including sex, age, and race/ethnicity.

Clinic EMR data were augmented with HIV surveillance data from the Minnesota Department of Health (MDH). CD4 counts and viral loads are reported statewide to the enhanced HIV/AIDS Reporting System (eHARS) database. Voluntary reporting of HIV-related laboratory test results began in 2008 and became mandatory in 2011. For each patient in the study

population, surveillance data were first used to determine whether the PCC was the current provider, defined as the patient's most recent HIV-related laboratory test result in eHARS having been reported by the PCC. For current PCC patients, all past laboratory test results reported to eHARS by other facilities were merged with the EMR data. For patients for whom the PCC was not the current provider, the first date of care from a non-PCC provider, either within Minnesota or out of state, was identified based on laboratory test results reported to eHARS. Date of death was provided from surveillance data for any patients who had died.

Personal identifiers were removed before the analysis.

Current patient care status

We determined the care status of each patient as of December 31, 2014 first using clinic data alone and again using both clinic and surveillance data. Patients who were not known to have died, relocated out of state, or changed providers were classified as “in-care” at the end of 2014 if they had at least one clinical encounter in the past 12 months. Otherwise, they were classified as “out of care.”

To understand the association between patient demographics and care status, we fit a multinomial log-linear regression of patient care status (determined from both clinic and surveillance data) to patient sex, race, age, whether they were a PCC patient before 2008, and if not, the number of years they had been attending the PCC. In the regression analysis, missing race/ethnicity was addressed using multiple imputation. A multinomial log-linear regression of race/ethnicity was fit to sex, age, and year of first PCC visit among those patients with complete data. We sampled from this distribution for patients with missing race/ethnicity 20 times and conducted regression analyses with each of the 20 samples. Regression results were pooled to generate final inferences.²⁴

Longitudinal retention-in-care measures

Retention in care was measured longitudinally for each patient. We first defined a patient-specific observation period for each patient in the study population. This observation period started with the patient's first date of registration at the PCC or on January 1, 2008, whichever occurred later. The observation period ended if the patient died, relocated, or changed providers, or on December 31, 2014 (the study end date), whichever occurred first.

Retention was calculated over the observation period using two different metrics: the proportion of years in which a patient satisfied the Health Resources and Services Administration (HRSA) criteria of having at least visits >90 days apart;^{25,26} and whether or not a patient had a gap of >12 months between clinical encounters.²⁶ For both measures, a clinical encounter was defined as either a clinic visit with a prescribing provider (medical doctor or nurse practitioner) or an HIV-related laboratory test. Retention measures were only calculated for patients with an observation period of at least 12 months.

We compared retention estimates under three different data scenarios, reflecting varying levels of integration between clinic and surveillance data. In the first scenario, retention was calculated using clinic EMR data alone, which is the current situation for providers in Minnesota. In the second scenario, surveillance information about end-point events

(death, relocation, change in provider) was combined with EMR data, which shortened the observation period for patients who experience an end-point event before the study end date. In the third data scenario, surveillance data on end-point events and statewide laboratory tests were integrated with clinic EMRs, which filled in gaps in care at the PCC with evidence of care from another provider, more accurately reflecting a patient's true engagement in care over time.

Potential impact of real-time data integration

We explored the potential impact of real-time integration of surveillance data on clinic re-engagement activities. We considered a hypothetical program where clinic staff initiate a case investigation and attempt to contact and re-engage a patient if the time since their last clinical encounter exceeded a given threshold, unless the clinic had been informed that the patient had moved, changed providers (as evidenced by a laboratory test result reported by a different provider), or died. We considered different time thresholds for initiating a

TABLE 1. DEMOGRAPHIC SUMMARY OF PATIENT POPULATION RECEIVING CARE AT THE HCMC POSITIVE CARE CLINIC DURING THE STUDY PERIOD

	n	%
Total patients	2194	100.0
Sex		
Male	1589	72.4
Female	605	27.6
Age in 2014		
<25	55	2.5
25–34	444	20.2
35–44	567	25.8
45–54	704	32.1
55–64	349	15.9
>65	75	3.4
Race		
White	838	38.2
Black	997	45.4
Hispanic	164	7.5
Other	176	8.0
Missing	19	0.9
Arrival at PCC		
Pre-2008	1017	46.4
2008	170	7.7
2009	181	8.2
2010	193	8.8
2011	205	9.3
2012	220	10.0
2013	208	9.5
Patient status (clinic data only)		
Current patient	1527	69.6
Out of care	658	30.0
Died	9	0.4
Patient status (w/surveillance data)		
Current patient	1475	67.2
Out of care	327	14.9
Changed providers	226	10.3
Moved out of state	106	4.8
Died	60	2.7

HCMC, Hennepin County Medical Center; PCC, Positive Care Clinic.

TABLE 2. DEMOGRAPHIC SUMMARY OF STUDY POPULATION BY STATUS AT THE END OF 2014

	Current patient	Out of care	Changed provider	Moved out of state	Died
	n (%)	n (%)	RR (95% CI)	RR (95% CI)	RR (95% CI)
Total, n (%)	1475 (67.2%)	327 (14.9%)	226 (10.3%)	106 (4.8%)	60 (2.7%)
Sex, n (%)					
Male	1052 (66.2%)	234 (14.7%)	Ref.	Ref.	Ref.
Female	423 (69.9%)	93 (15.4%)	0.78 (0.55–1.11)	0.68 (0.41–1.13)	0.92 (0.49–1.74)
Race, n (%)					
White	555 (66.2%)	100 (11.9%)	Ref.	Ref.	Ref.
Black	685 (68.7%)	166 (16.6%)	1.34 (1.01–1.77)*	0.83 (0.53–1.28)	0.61 (0.34–1.10)
Hispanic	114 (69.5%)	30 (18.3%)	1.33 (0.84–2.11)	0.45 (0.17–1.16)	0.62 (0.18–2.09)
Other	115 (65.3%)	24 (13.6%)	1.09 (0.66–1.80)	0.70 (0.30–1.63)	0.88 (0.32–2.42)
Missing	6 (31.6%)	7 (36.8%)	N/A	N/A	N/A
Age, mean (SD)	45.2 (4.0)	43.0 (3.7)	0.98 (0.96–0.99) [†]	0.96 (0.95–0.98) [‡]	1.04 (1.01–1.06) [†]
Patient before 2008, n (%)					
No	736 (62.5%)	198 (16.8%)	Ref.	Ref.	Ref.
Yes	739 (72.7%)	129 (12.7%)	1.40 (0.83–2.35)	1.28 (0.62–2.63)	3.96 (1.10–14.30)*
Among patients arriving in 2008 or later					
Years since arrival, mean (SD)	3.2 (1.9)	3.6 (2.2)	1.20 (1.09–1.32) [‡]	1.28 (1.11–1.48) [†]	1.19 (0.88–1.61)

RRs are relative to being currently in care and were estimated from a multinomial log-linear regression model of patient status.

* $p < 0.05$, [†] $p < 0.01$, [‡] $p < 0.001$.

CI, confidence interval; N/A, not applicable; RR, relative risk.

case investigation, ranging from 8 to 24 months since their previous clinical encounter. For each threshold, we calculated the total number of required case investigations over the study period with and without surveillance data integration. We then computed the number of case investigations averted by surveillance data integration to quantify the value of data sharing between surveillance and clinic systems.

To determine which types of patients were the most impacted by surveillance data integration, we fit a multiple logistic regression model of the probability of having a case investigation averted among those patients who required at least one case investigation over their observation period when using a 12-month threshold for initiating an investigation. Missing race/ethnicity was again addressed by using multiple imputation, as previously described.²⁴

Software

All statistical analyses were performed in R 3.1.3,²⁷ using the *mi* package for multiple imputation²⁸ and the *nnet* package for fitting multinomial regression models.²⁹

Results

Study population characteristics

There were 2194 HIV+ patients ≥18 years old who were seen at the PCC between 2008 and 2013. The study population was 72.4% male, with an average age of 44.5 in 2014 (Table 1). In EMR data, 38.2% of the study population self-identified as white and 45.4% self-identified as black. Race was missing for 19 (0.9%) patients. A little less than half of the study population (46.4%) had established care at the PCC before 2008. The number of new patients establishing care each year increased over the study period from 170 in 2008 to 208 in 2013.

Current patient care status

With clinic data alone, 30% of the study population appeared to be out of care (having no evidence of care within the past 12 months) at the end of 2014 (Table 1). The integration of surveillance data with clinic EMR data reduced this estimate by half to 14.9% by providing information regarding patient mortality, relocation out of state, and receiving care at another provider. Surveillance data indicated that by the end of 2014, 4.8% of patients had moved out of state and 10.3% had changed providers within Minnesota. Sixty (2.7%) patients died during the study period according to surveillance records, but only nine of these deaths were noted in the clinic's EMRs.

Patients identifying as black or Hispanic were more likely to be out of care and less likely to have moved or changed pro-

viders than patients identifying as white (Table 2). Those who had initiated care at the PCC before 2008 were more likely to have died than those who started receiving care at the PCC more recently. For those who arrived at the PCC in 2008 or later, the number of years in care was positively associated with an increasing likelihood of being out of care, changing provider, or moving out of state. Younger age was associated with changing providers or moving out of state, whereas older age was associated with a higher likelihood of death.

Longitudinal retention-in-care estimates

The average observation period decreased from 5.3 years using clinic data alone to 4.9 years when surveillance end-point data were included (Table 3). Nearly all patients (2192 of 2194) had sufficient observation time according to clinic records, but with the integration of surveillance records this decreased to 2121 due to end-point events occurring within the first observed 12 months.

The observed HRSA compliance among patients increased from an average of 70.3% with clinic data alone to 76.2% when surveillance end-point information was incorporated. HRSA compliance estimates further increased to 77.5% with the addition of surveillance laboratory records. The proportion of patients who experience a gap between clinical encounters longer than 12 months decreased from 986 (45.0%) using clinic data alone to 770 (36.3%) with surveillance end-points and to 730 (34.4%) when surveillance information was fully integrated.

Case investigations averted

The number of required case investigations over the study period using clinic data alone ranged from 1945 for an 8-month threshold on the time since previous clinical encounter to 592 investigations using a 24-month threshold (Fig. 1). The proportion of investigations averted increased as the time threshold for initiating a case investigation increased, though in absolute terms the number of case investigations averted was similar. For 8-, 12-, and 24-month thresholds, surveillance data integration averted 328 (16.9%), 330 (29.4%), and 262 (44.3%) of investigations, respectively. Patients who identified as black or Hispanic were less likely to be impacted by surveillance data integration than those who identified as white (Table 4).

Discussion

Integration of surveillance data with clinical records reduced the number of patients who appeared to be out of care by half, which is similar to estimates from other settings.^{18–21} Data integration also improved retention-in-care metrics and

TABLE 3. SUMMARY OF RETENTION-IN-CARE MEASURES, BY LEVEL OF DATA INTEGRATION

	<i>Clinic data</i>	<i>Clinic data with surveillance end-points</i>	<i>Clinic data with full surveillance data</i>
Average observation time, years	5.3 (SD: 2.0)	4.9 (SD: 2.2)	4.9 (SD: 2.2)
Has at least 1 full year of observation time	2192 (99.9%)	2121 (96.7%)	2121 (96.7%)
Average HRSA compliance	70.3% (SD: 35.0%)	76.3% (SD: 32.3%)	77.6% (SD: 31.7%)
100% HRSA compliance over observation period	1022 (46.6%)	1147 (54.1%)	1182 (55.7%)
Had a gap of >12 months	986 (45.0%)	770 (36.3%)	730 (34.4%)

HRSA, Health Resources and Services Administration.

FIG. 1. Number of case investigations required over the study period with and without surveillance data integration. The threshold on the time since previous clinical encounter to initiate a case investigation was varied from 8 to 24 months.

averted a substantial number of unnecessary case investigations by updating a patient's status before an investigation was initiated. Prevention of unnecessary case investigations would reduce waste and allow limited resources for patient re-engagement to be better targeted to those who truly need them. Previous studies have demonstrated a decreasing probability of reaching patients the longer they have been out of care.²⁰ Access to surveillance information would reduce investigation case loads, allowing clinics to reach out to patients more quickly to re-engage them back into care.

Identifying as white and being of a younger age were associated with a higher likelihood of changing provider or

relocating out of state, indicating a higher degree of mobility. Conversely, identifying as black or Hispanic was associated with a higher probability of being out of care. Surveillance information was also less likely to avert unnecessary case investigations among black and Hispanic patients. Even without real-time surveillance data integration, these findings could be used to prioritize re-engagement efforts to those who are the most likely to be truly out of care.

Among patients who initiated care at the PCC during the study period, the time since arrival at the clinic had significant associations with being out of care, changing providers, and relocating out of state. This is a somewhat intuitive

TABLE 4. DEMOGRAPHIC SUMMARY PATIENTS IMPACTED BY SURVEILLANCE DATA INTEGRATION

	Had case investigation averted?		OR (95% CI)
	Yes	No	
Total, <i>n</i> (%)	649 (67.0%)	319 (33.0%)	
Sex, <i>n</i> (%)			
Male	475 (65.9%)	246 (34.1%)	Ref.
Female	174 (70.4%)	73 (29.6%)	0.90 (0.65–1.26)
Race, <i>n</i> (%)			
White	227 (59.6%)	154 (40.4%)	Ref.
Black	309 (71.7%)	122 (28.3%)	0.61 (0.45–0.82)*
Hispanic	45 (77.6%)	13 (22.4%)	0.43 (0.22–0.83)*
Other	58 (69.0%)	26 (31.0%)	0.70 (0.42–1.18)
Missing	10 (71.4%)	4 (28.6%)	N/A
Age, mean (SD)	42.8 (4.0)	43.8 (3.7)	1.01 (1.00–1.02)
Patient before 2008, <i>n</i> (%)			
No	358 (66.4%)	181 (33.6%)	Ref.
Yes	291 (67.8%)	138 (32.2%)	1.19 (0.69–2.05)
Among patients arriving in 2008 or later			
Years since arrival, mean (SD)	3.8 (1.9)	4.0 (2.2)	1.08 (0.96–1.21)

ORs were estimated from a logistic regression model of whether or not a patient had a case investigation averted.

**p* < 0.01.

CI, confidence interval; N/A; OR, odds ratio.

finding, as patients who have been in care longer have had more time to move or drop out from care. This perhaps also indicates that attrition is not an immediate process, with opportunities to strengthen engagement among those patients who may be at risk for dropping out of care.

The use of surveillance data for activities beyond the traditional public health responsibilities of health departments (e.g., monitoring and partner notification) is potentially controversial. However, in the case of HIV, ethical analyses have generally concluded that sharing surveillance information to improve patient linkage and engagement in care is not only permissible but perhaps even obligatory given the clear demonstrated clinical and public health benefits of antiretroviral treatment coupled with regular medical care for HIV patients and their communities.³⁰ Accordingly, many state privacy laws and/or HIV surveillance policies allow data sharing with healthcare providers for the purposes of improving clinical care for HIV patients.³¹ However, in many states, including Minnesota, sharing of surveillance information with healthcare providers is ad hoc. Implementation of a more automated and proactive data-sharing system faces substantial logistical, legal, and security challenges. However, as this analysis has demonstrated, such a system could have a substantial impact on clinical care by informing providers and clinics in a more timely manner when a patient is no longer under their care, allowing their efforts to be refocused on caring for current patients and re-engaging patients who are truly out of care.

Despite the considerable strengths of our study, we acknowledge several potential limitations. Incomplete or delayed reporting to HIV surveillance systems may lead to inaccuracies in determining current patient care status and measuring retention over time. Multiple studies have highlighted deficiencies in HIV surveillance data in determining retention in care. When case investigations were undertaken for patients who appeared to be out of care according to both clinic and surveillance records, a substantial proportion of patients were found to be receiving care elsewhere, had relocated outside a clinic's catchment area, or had died.^{18,20,32–35} Thus, data integration does not guarantee complete accuracy. However, even with an imperfect surveillance system, we demonstrate substantial gains in reducing unnecessary case investigations, allowing resources to be better targeted among those still suspected of being out of care. Further, as surveillance systems evolve to better capture patient care dynamics, clinics would also benefit from the improved accuracy, making data integration even more valuable.

Due to data-sharing restrictions, we were unable to obtain information about HIV risk categories or date of initial HIV diagnosis for all patients in the study population, so these characteristics were not included in statistical analyses. In our analysis of case investigations averted by data integration, we considered only the number of case investigations that would be required under different scenarios, but we did not consider the impact of these re-engagement efforts on patient outcomes or future care dynamics.

In summary, our study found that integration of surveillance data with clinical records reduced the number of patients who appeared to be out of care at the end of 2014 by 50% and would have averted 29.4% of required case investigations between 2008 and 2014 to re-engage patients without evidence of care in the past 12 months. These results

highlight the potential benefits of surveillance data integration for improving the efficiency of HIV care by allowing outreach resources to be better targeted to those who need them. In an era of tightening healthcare budgets and a growing emphasis on population health management, it is critical for healthcare providers and clinics to find ways of leveraging existing systems to improve the efficiency and efficacy with which they manage patients both in and out of care. Our analysis illustrates the benefits to clinic operations and patient care that could be realized through closer data-sharing relationships between state public health departments and providers who care for PLWH.

Acknowledgments

This research was supported by a grant from the National Institute for Allergy and Infectious Diseases at the National Institutes of Health under award number K25AI118476 (PI: Enns). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. The authors wish to acknowledge Allison La Pointe at the Minnesota Department of Health and Jessica Bremer, formerly of the Minnesota Department of Health, for their role in the study design and merging state surveillance data.

Author Disclosure Statement

No competing financial interests exist.

References

- Office of National AIDS Policy. National HIV/AIDS strategy: Updated to 2020. Washington, DC, 2015.
- Giordano TP, Gifford AL, White AC, et al. Retention in care: A challenge to survival with HIV infection. *Clin Infect Dis* 2007;44:1493–1499.
- Mugavero MJ, Lin H-Y, Willig JH, et al. Missed visits and mortality among patients establishing initial outpatient HIV treatment. *Clin Infect Dis* 2009;48:248–256.
- Horberg MA, Hurley LB, Silverberg MJ, Klein DB, Quesenberry CP, Mugavero MJ. Missed office visits and risk of mortality among HIV-infected subjects in a large healthcare system in the United States. *AIDS Patient Care STDs* 2013;27:442–449.
- Valdez H, Lederman MM, Woolley I, et al. Human immunodeficiency virus 1 protease inhibitors in clinical practice: Predictors of virological outcome. *Arch Intern Med* 2014;159:1771–1776.
- Sethi AK, Celentano DD, Gange SJ, Moore RD, Gallant JE. Association between adherence to antiretroviral therapy and human immunodeficiency virus drug resistance. *Clin Infect Dis* 2003;37:1112–1118.
- Rastegar DA, Fingerhoo MI, Jasinski DR. Highly active antiretroviral therapy outcomes in a primary care clinic. *AIDS Care* 2003;15:231–237.
- Berg MB, Safren SA, Mimiaga MJ, Grasso C, Boswell S, Mayer KH. Nonadherence to medical appointments is associated with increased plasma HIV RNA and decreased CD4 cell counts in a community-based HIV primary care clinic. *AIDS Care* 2005;17:902–907.
- Park WB, Choe PG, Kim S-H, et al. One-year adherence to clinic visits after highly active antiretroviral therapy: A predictor of clinical progress in HIV patients. *J Intern Med* 2007;261:268–275.

10. Ulett KB, Willig JH, Lin H-Y, et al. The therapeutic implications of timely linkage and early retention in HIV care. *AIDS Patient Care STDs* 2009;23:41–49.
11. Horstmann E, Brown J, Islam F, Buck J, Agins BD. Retaining HIV-infected patients in care: Where are we? Where do we go from here? *Clin Infect Dis* 2010;50:752–761.
12. Yehia BR, French B, Fleishman JA, et al. Retention in care is more strongly associated with viral suppression in HIV-infected patients with lower versus higher CD4 counts. *J Acquir Immune Defic Syndr* 2014;65:333–339.
13. Attia S, Egger M, Müller M, Zwahlen M, Low N. Sexual transmission of HIV according to viral load and antiretroviral therapy: Systematic review and meta-analysis. *AIDS* 2009;23:1397–1404.
14. Reynolds SJ, Makumbi F, Nakigozi G, et al. HIV-1 transmission among HIV-1 discordant couples before and after the introduction of antiretroviral therapy. *AIDS* 2011;25:473–477.
15. Cohen MS, Chen YQ, McCauley M, et al. Prevention of HIV-1 infection with early antiretroviral therapy. *N Engl J Med* 2011;365:493–505.
16. Centers for Disease Control and Prevention (CDC). Monitoring selected national HIV prevention and care objectives by using HIV surveillance data—United States and 6 U.S. dependent areas—2013. *HIV Surveillance Suppl. Rep.* Atlanta, GA; 2015. Available at: www.cdc.gov/hiv/library/reports/surveillance/ (Last accessed April 26, 2016).
17. West TL. Strategic Information in DC: Uses of Public Health Data for Evidence Based Role of Public Health Information. Washington, DC: HIV/AIDS, Hepatitis, STD, and TB Administration, 2011. Available at: http://www.uchaps.org/assets/DC_Strategic_Info_West.pdf (Last accessed August 26, 2016).
18. Bove JM, Golden MR, Dhanireddy S, Harrington RD, Dombrowski JC. Outcomes of a clinic-based surveillance-informed intervention to relink patients to HIV care. *J Acquir Immune Defic Syndr* 2015;70:262–268.
19. Wohl AR, Dierst-Davies R, Victoroff A, et al. Implementation and operational research: The navigation program: An intervention to reengage lost patients at 7 HIV clinics in Los Angeles county, 2012–2014. *J Acquir Immune Defic Syndr* 2016;71:e44–e50.
20. Christopoulos KA, Scheer S, Steward WT, et al. Examining clinic-based and public health approaches to ascertainment of HIV care status. *J Acquir Immune Defic Syndr* 2015;69 Suppl 1:S56–S62.
21. Lubelchek RJ, Finnegan KJ, Hotton AL, et al. Assessing the use of HIV surveillance data to help gauge patient retention-in-care. *J Acquir Immune Defic Syndr* 2015;69: S25–S30.
22. Division of HIV/AIDS Prevention. HIV and AIDS in the United States by Geographic Distribution. Atlanta; 2012. Available at: www.cdc.gov/hiv/statistics/overview/geographicdistribution.html (Last accessed May 10, 2016).
23. Minnesota Department of Health. HIV/AIDS Prevalence and Mortality Tables—2013. St. Paul, MN; 2014. Available at: www.health.state.mn.us/divs/idepc/diseases/hiv/stats/2013 (Last accessed April 26, 2016).
24. Rubin D. Multiple imputation after 18+ years. *J Am Stat Assoc* 1996;91:473–489.
25. Health Resources and Services Administration (HRSA). Guide for HIV/AIDS Clinic Care. Rockville, MD, 2014. Available at: <http://hab.hrsa.gov/deliverhivaidscares/clinicalguidelines.html> (Last accessed April 26, 2016).
26. Yehia B, Fleishman J. Comparing different measures of retention in outpatient HIV care. *AIDS* 2012;26:1131–1139.
27. R Core Team. R: A language and environment for statistical computing. Vienna, Austria; 2015. Available at: www.r-project.org/ (Last accessed August 26, 2016).
28. Su Y-S, Gelman A, Hill J, Yajima M. Multiple imputation with diagnostics (mi) in R: Opening windows into the black box. *J Stat Softw* 2011;45:1–31.
29. Venables W, Ripley B. *Modern Applied Statistics with S*, 4th ed. New York: Springer, 2002.
30. Sweeney P, Gardner LI, Buchacz K, et al. Shifting the paradigm: Using HIV surveillance data as a foundation for improving HIV care and preventing HIV infection. *Milbank Q* 2013;91:558–603.
31. O'Connor JG. Informational privacy, public health, and state laws. *Am J Public Health* 2011;101:1845.
32. Buchacz K, Chen MJ, Parisi MK, et al. Using HIV surveillance registry data to re-link persons to care: The RSVP project in San Francisco. *PLoS One* 2015;10:1–14.
33. Dombrowski JC, Buskin SE, Bennett A, Thiede H, Golden MR. Use of multiple data sources and individual case investigation to refine surveillance-based estimates of the HIV care continuum. *J Acquir Immune Defic Syndr* 2014;67:323–330.
34. Buskin SE, Kent JB, Dombrowski JC, Golden MR. Migration distorts surveillance estimates of engagement in care: Results of public health investigations of persons who appear to be out of HIV care. *Sex Transm Dis* 2014;41:35–40.
35. Udeagu C-CN, Webster TR, Bocour A, Michel P, Shepard CW. Lost or just not following up. *AIDS* 2013;27:2271–2279.

Address correspondence to:

Eva A. Enns, PhD, MS

Division of Health Policy and Management

University of Minnesota School of Public Health

420 Delaware Street, SE, MMC 729

Minneapolis, MN 55455

E-mail: eenns@umn.edu