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Combinations of interventions to achieve a national HIV incidence reduction goal: Insights from the agent-based PATH 2.0 model

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Abstract

Objective—Analyzing HIV care service targets for achieving a national goal of a 25% reduction in annual HIV incidence and evaluating the use of annual HIV diagnoses to measure progress in incidence reduction.

Design—Because there are considerable interactions among HIV care services, we model the dynamics of *combinations* of increases in HIV care continuum targets to identify those that would achieve 25% reductions in annual incidence and diagnoses.

Methods—We used Progression and Transmission of HIV/AIDS (PATH 2.0), an agent-based dynamic stochastic simulation of HIV in the United States.

Results—A 25% reduction in annual incidence could be achieved by multiple alternative combinations of percentages of persons with diagnosed infection and persons with viral suppression including 85% and 68%, respectively, and 90% and 59%, respectively. The first combination corresponded to an 18% reduction in annual diagnoses, and infections being diagnosed at a median CD4 count of 372 cells/ μ L or approximately 3.8 years from time of

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Conflicts of Interest

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infection. The corresponding values on the second combination are 4%, 462 cells/ μ L, and 2.0 years, respectively.

Conclusions—Our analysis provides policy makers with specific targets and alternative choices to achieve the goal of a 25% reduction in HIV incidence. Reducing annual diagnoses does not equate to reducing annual incidence. Instead, progress toward reducing incidence can be measured by monitoring HIV surveillance data trends in CD4 count at diagnosis along with the proportion who have achieved viral suppression to determine where to focus local programmatic efforts.

Keywords

National HIV/AIDS Strategy; NHAS; HIV intervention combinations; agent-based simulation model; HIV simulation model

Introduction

Approximately 1.2 million people in the United States are living with human immunodeficiency virus (HIV) infection. The Centers for Disease Control and Prevention (CDC) reported that the number of diagnoses in 2014 was 40,493 compared with 43,806 in 2010. (1) Estimated annual HIV incidence in 2013 was 39,000 compared with 43,200 in 2010, based on CD4 test results from people with diagnosed HIV and a CD4 depletion model. (2)

In 2010, the White House published the National HIV/AIDS Strategy (NHAS), which included the goal of reducing annual HIV incidence by 25% by 2015.(3) In 2015, the White House published an updated NHAS with HIV prevention and care goals to be achieved by 2020.(4) Because of challenges in estimating HIV incidence, a 25% reduction in the annual number of new diagnoses compared with 2010 replaced, and was meant to serve as a proxy for, the 25% targeted reduction in incidence. The rationale for using data on new diagnoses for the goal was that they are routinely reported to CDC's National HIV Surveillance System, are available on the national as well as the local level, and are more current than data on HIV incidence.(3,4) Incidence estimates require statistical modeling techniques that may vary over time and generate results that may not be available in a timely manner.(4)

The 2015 update proposed national HIV prevention goals for year 2020 for increasing the proportion of persons living with HIV (PLWH) who achieve each step of the HIV care continuum including: (1) increasing the percentage of PLWH with diagnosed HIV to 90%, (2) increasing the percentage of persons with newly diagnosed HIV who are linked to care within one month of diagnosis to 85%, and (3) increasing the percentage of persons living with diagnosed HIV who have suppressed viral loads to 80%. The equivalent values in year 2010 were 85%, 82%, and 33%, respectively.(5)

Although these specific continuum of care goals were proposed, it is possible that numerous combinations of targets for increasing percentage diagnosed, linkage to care, and viral load suppression could generate a 25% decrease in HIV incidence or annual diagnoses. Understanding which combinations of targets would achieve the goals for decreasing incidence or diagnoses may be useful for decision makers and program directors who must

decide how best to allocate HIV prevention resources. The use of new diagnoses as a proxy for new infections has also been debated and merits further analysis. (6)

Methods

We used the Progression and Transmission of HIV/AIDS (PATH 2.0) model of HIV in the United States to set the continuum of care targets, percentage of PLWH with diagnosed HIV, percentage of newly diagnosed linked to care, and percentage of persons living with diagnosed HIV who have viral suppression, to be achieved by 2020 and to simulate the outcomes, reductions in new infections and new diagnoses, from 2010 to 2020.

PATH 2.0 is an agent-based stochastic simulation that individually tracks HIV-infected persons, simulating HIV disease progression through a health-state transition model and sexual transmissions of HIV through a novel evolving dynamic transmission model. Details of the model are presented elsewhere (7) and are summarized in the Appendix.

To use PATH to determine the complete set of combinations of continuum targets that would generate a 25% reduction in annual HIV infections or HIV diagnoses, we assumed an acceptable range of continuum target values as: 81% to 95% for percentage of PLWH with diagnosed HIV (15 possible choices); 81% to 95% for percentage linked to care (15 possible choices); and 31% to 70% for percentage with viral suppression (40 possible choices), to generate 9,000 ($15 \times 15 \times 40$) different scenarios to simulate using the PATH model. Running this many combinations is impractical because of the long computational time of individual-based simulation models. Instead, we sampled a subset of 40 combinations to simulate using the Latin hypercube sampling method. In Latin hypercube sampling, each variable is stratified into a pre-determined number of intervals, and combinations are selected such that each interval is picked at least one time.(8) Aiming for small interval sizes (spanning changes of 1 percentage point or less), we chose a sample size of 40, which reflects the maximum difference in percentage points among the variable ranges considered, i.e., percentage with viral suppression has a range of 40 (31%-70%), and percentages diagnosed and linked to care each have a range of 15 (81%-95%).

Then, we simulated each selected combination of inputs for percentages diagnosed, linked to care and with viral suppression in the PATH 2.0 model and extracted the results. We generated the percent reduction in each outcome, annual infections and diagnoses in 2020 compared to 2010, as $[\text{outcome in 2020} - \text{outcome in 2010}] / [\text{outcome in 2010}]$. Because PATH keeps track of HIV-infected persons individually, including the CD4 count at diagnosis for each simulation run, we also extracted the median CD4 count at diagnosis among all persons with HIV diagnosed in 2020 in the simulation run. These data enabled us to estimate the CD4 count required at diagnosis in 2020 to achieve the corresponding combination of percentages diagnosed, linked to care, and with viral suppression that would generate the target outcomes. From the estimated CD4 counts at diagnosis, we derived the median years from infection to diagnosis by assuming a median of 1.2, 4.2, and 7.9 years from seroconversion to CD4 counts dropping to <500, <350, and <200 cells/ μL , respectively, without ART. (9)

We applied regression modeling to the simulated results from PATH to generate three meta-models, one each for percent reduction in annual infections and annual diagnoses, as well as one for the CD4 count at diagnosis, all as functions of D = percentage of PLWH with diagnosed HIV, V = percentage of persons living with diagnosed HIV who have viral suppression, and L = percentage of persons newly diagnosed with HIV who are linked to care. Meta-models are a transformation of the simulation model into an analytical equation, so that, for different values of input measures we can calculate the outcome measures by directly using the equation instead of simulating. (10) To generate each meta-model, we evaluated $\overline{m}_j = f(D, V, L)$, taking $f(D, V, L)$ to be equations with linear (e.g., D), quadratic (e.g., D^2), and interaction (e.g., DV) terms to fit an equation, i.e., solve for the coefficient values (β_i), for each term i that would minimize $\sum_{j=1}^{N=40} (m_j - \overline{m}_j)^2$, where m_j is the outcome of interest generated from PATH for a specific combination(j) of D , V , and L , and $\overline{m}_j$ is the outcome of interest calculated using the meta-model equation for the same combination of D , V , and L . We used the MATLAB optimization toolbox to solve for β_i 's. We then used the meta-models to directly calculate the outcome measures for any given combination of D , V , L , even those outside of the 40 combinations simulated.

We simulated each of the 40 scenarios (combinations of D , V , and L) 35 times to estimate the 10th, 50th, and 90th percentile values of the outcome variables, and fit meta-models for each. We used the fitted meta-models with the 50th percentile values to generate contour graphs of the reduction in annual infections and diagnoses for all possible combinations of percentages diagnosed, linked to care and with viral suppression. For each combination, we indicated the associated median CD4 count at diagnoses required to achieve the goal. We validated the meta-model by randomly selecting 40 additional samples and comparing the simulated results with results from the meta-models (see Appendix).

Results

Variations in the percentage of persons with newly diagnosed HIV who were linked to care within 1 month from 80% to 95% had little effect on the model's simulated number of annual infections or diagnoses. Therefore, we fixed the proportion linked to care at 85%, which is close to the 82% linkage to care reported by HIV surveillance data for 2011 and consistent with the 2015 and 2020 national HIV prevention goals.

Multiple combinations of percentage diagnosed and percentage with viral suppression generated the prevention goal of a 25% reduction in annual HIV infections by 2020 (Figure 1, Table 1), and there is a trade-off between percent diagnosed and percent with viral suppression to achieve this goal. For example, the goal could be achieved when 85% of people living with HIV had their infection diagnosed by 2020, and 68% (63% to 71%) of those with diagnosed HIV had achieved viral suppression (Figure 1, point A; Table 1, Scenario 1). This combination is equivalent to infections being diagnosed at a median CD4 count of 372 cells/ μ L (348 to 397 cells/ μ L) in 2020, i.e., diagnosis would need to occur approximately 3.8 years (4.2 to 3.3 years) from the time of infection. Instead if, by 2020, 90% of persons with HIV had their infection diagnosed, meeting the 25% reduction in new infections target would require only 59% (54% to 62%) of those diagnosed to achieve viral

load suppression (Figure 1, point B; Table 1, Scenario 2). This case is equivalent to infections being diagnosed at a median CD4 count of 462 cells/ μ L (449 to 477 cells/ μ L), i.e., diagnosis would need to occur approximately 2.0 years (2.2 to 1.7 years) from the time of infection.

Different combinations of percentage diagnosed and percentage with viral suppression also generated outcomes that fell short of or exceeded the prevention goal of a 25% reduction in annual infections (Figure 2, Table 2). For example, if 90% of persons with HIV had their infection diagnosed in 2020 but only 34% of persons with diagnosed HIV had achieved viral load suppression, there would be no reduction in annual infections in 2020 compared with 2010. If 90% were diagnosed and 44% of the diagnosed had achieved viral suppression, then the reduction in annual infections would be 10%. If 90% were diagnosed and 73% had achieved viral suppression, there would be a 40% reduction in annual infections, exceeding the prevention target by 15 percentage points.

In contrast to achieving the goal of a 25% reduction in annual infections, where increases in percentage diagnosed could be offset by decreases in percentage with viral suppression, achieving and maintaining the 2020 national HIV prevention goal of decreasing new diagnoses by 25% required that increases in percent diagnosed be accompanied by increases in percent with viral suppression (Figure 1). For example, when 85% of infections were diagnosed, then 78% (72% to 83%) of persons with diagnosed HIV had to achieve viral load suppression (Figure 1, point D; Table 1, Scenario 3). When 90% were diagnosed, then 81% (77% to 84%) of persons with diagnosed HIV had to achieve viral load suppression (Figure 1, point C; Table 1, Scenario 4). Figure 1 indicates only one combination of percentages diagnosed and viral suppression that achieved both a 25% reduction in new infections and new diagnoses (Figure 1, point E).

The 2020 prevention goal of decreasing annual diagnoses by 25% could result either from reducing annual infections, so that there are fewer infections to diagnose, or by reducing testing activity. Point B in Figure 1 illustrates that if 90% of infections were diagnosed and 59% of those with diagnosed infections achieved viral load suppression, there would be a 25% reduction in annual infections. However, that combination resulted in only a 4% reduction in new diagnoses (Table 1, Scenario 2). A 25% reduction in new diagnoses would be achieved with 90% of infections diagnosed only if 81% of those with diagnosed infection achieved viral suppression instead of 59% (Figure 1, Point C, Table 1, Scenario 4), which would then reduce new infections, illustrating a case with fewer infections to diagnose.

On the other hand, Point D illustrates a 25% reduction in diagnoses due to reduced testing activity rather than preventing more infections. A smaller percentage (78%) of those with diagnosed HIV were required to have viral suppression compared with Point C (81%), meaning that more infections occurred compared with Point C. However, in addition, a smaller proportion (85%) of those infected are receiving an HIV diagnosis compared with Point C (90%).

The differential relationship between combinations of percentage diagnosed and percentage with viral suppression on the percentage reductions in annual infections versus annual

diagnoses is illustrated by the following two cases (Figure 2). Case 1: Holding the percentage diagnosed constant and increasing the percentage with viral suppression increases both the percentage reduction in annual infections and the percentage reduction in annual diagnoses. Annual infections decrease because of fewer transmissions when more persons have viral suppression, which results in a larger percentage reduction in annual infections. Annual diagnoses decrease because there are fewer new infections to diagnose, which results in a larger percentage reduction in new diagnoses. Case 2: Holding the percent with viral suppression constant and increasing the percent diagnosed increases the percentage reduction in annual infections, but decreases the percentage reduction in diagnoses. An increase in percent diagnosed results in a larger number of diagnoses and thus a decrease in the percent reduction in annual diagnoses. Because of behavior change from diagnosis and awareness of infection, an increase in the percent diagnosed results in a smaller number of annual infections, and thus an increase in the percentage reduction in new infections.

Discussion

We have estimated the extent to which, by 2020, persons living with HIV would have to have their infections diagnosed, persons who receive a diagnosis would have to be linked to care, and persons living with diagnosed HIV would have to achieve viral suppression to achieve the national goals of 25% reductions in annual HIV incidence and diagnoses. We found that as long as at least 80% of persons who received a diagnosis of HIV were linked to care, that factor contributed little to reductions in new HIV cases, and that numerous combinations of percentages of persons with diagnosed infection and persons with viral suppression could achieve a 25% reduction in annual infections. Corresponding to each combination of percentage of persons with diagnosed infection and percentage with viral suppression, we also have presented the median CD4 counts at diagnosis and length of time from infection that diagnosis would have to occur. These measures together can help health departments fine-tune their prevention efforts. Specifically,

1. The length of time since infection that diagnosis should occur and the percentage with viral suppression relate to changes needed in testing programs (such as altering testing frequency, as shorter length of times to diagnosis indicate more frequent testing) and retention in care programs (such as promoting ART retention and adherence), respectively. The trade-off in these measures indicates that more modest increases in testing programs to increase diagnosis will require more solid advances in retention in care programs to increase viral load suppression and vice-versa. The decision on what combination to choose can be based on costs and population compliance to these interventions.
2. The targeted median CD4 counts at diagnoses and percentage with viral suppression can be dynamically compared with most current values of these measures in the population, which are monitored annually through HIV surveillance, to determine program expansion. Targeting higher median CD4 counts means that testing efforts must be improved so that diagnosis occurs closer to the time of infection. Targeting higher percentage viral load suppression

means retention in care programs should improve so that treatment adherence increases.

Our model employs 2010 baseline estimates for percent diagnosed, linked to care, and viral suppression, consistent with the timeframes for achieving reductions by 2020. The most recent national estimates for those HIV continuum-related targets are 85% diagnosed (2014), 82% linked to care in 3 months (75% in one month) (2014), and 58% of those with diagnosed infection with viral suppression (2014), indicating continuing progress toward meeting the prevention goals (11). Recent CDC estimates indicate a 14% reduction in annual infections from sexual transmissions between 2008 and 2014 and a 5% reduction in new diagnosis between 2010 and 2014 (12)(13). Among the scenarios we simulated, the closest to these 2014 continuum targets was the scenario with 83% diagnosed and 51% with viral suppression in 2014, which generated a 10% reduction in new infections between 2008 and 2014 and a 4% reduction in new diagnosis between 2010 and 2014 (results not shown).

Assuming that the proportion of those living with HIV with diagnosed infection will continue be maintained at 85% through 2020, our model suggests that viral load suppression among 68% of those with diagnosed HIV (linearly scaled-up from 2010 to 2020) would be sufficient to achieve the 25% reduction in incidence by 2020. On the other hand, an 80% target for viral load suppression by 2020, consistent with prevention goals, combined with 85% diagnosis, would achieve a 36% reduction in incidence. Meeting both the prevention goals of an 80% target for viral load suppression and a 90% target for diagnosis by 2020 would achieve a 47% reduction in incidence.

We found that higher proportions of persons living with HIV who had their infection diagnosed translated into higher median CD4 counts at diagnosis, or the occurrence of diagnosis closer to the time of infection. Achieving this result could include identifying high-risk groups who typically receive a diagnosis later in the course of their infection, i.e., with lower CD4 counts at the time of diagnosis, and devising strategies to test those groups more frequently or more comprehensively. In 2014, among persons with diagnosed HIV in 27 states and the District of Columbia, 24.4% had CD4 counts at 500 or above at diagnosis, 31.7% had counts at 200 to 499, 22.7% had counts of 200 or below, and 21.2% did not have data on CD4 count at the time of diagnosis (14). Our analysis suggests that diagnosis at median CD4 counts between 370 and 470 would be needed to diagnose 85% to 90% of infections among all persons living with HIV.

We found that reductions in annual HIV diagnoses did not usually equate to reductions in annual HIV infections. Reductions in annual diagnoses can occur even as annual infections are increasing if less testing occurs, and increases in annual diagnoses can occur even while annual infections are declining if testing increases. Diagnoses may only be a good proxy for infections when diagnosis occurs almost immediately after infection (15). New methods for estimating HIV incidence may in the future make these estimates more readily available for measuring progress in HIV prevention.(2)

While a recent paper estimated the effects on HIV incidence of reaching specific NHAS HIV continuum targets related to diagnosis/awareness of infection, linkage to care and maintenance in care (16), our focus on combinations of the continuum strategies of

diagnosis, linkage to care, and viral load suppression that would achieve the NHAS goal of a 25% reduction in incidence provides flexibility in considering how to reduce incidence. Communities that already have achieved the targeted levels of diagnosis may choose to focus their resources on prescription of and adherence to ART, and vice versa.

Our model is subject to certain limitations. The sexual behavior data are subject to reporting bias, given that most of these data are self-reported. Additional bias could result from integrating data from independent surveillance systems, which have varying definitions for many variables, particularly those reflecting HIV-infected persons' movement along the continuum of care. We did not include sexual transmissions to or from persons who inject drugs, and did not consider spatial differences in care and behavior. This could have resulted in smaller or larger transmission rates for MSM and heterosexuals because we do not know how many transmissions in these groups resulted from sexual mixing with persons who inject drugs. In addition, PATH 2.0's transmission modeling technique of building partnerships of HIV-infected persons over time, unlike traditional individual-based techniques of modeling all infected and uninfected persons, is subject to a small margin of error (7). As in any model, due to the dynamic nature of infectious diseases, the impacts of the same strategy could vary over time as the baseline values change. We used baseline estimates up to 2010, which were the latest estimates available at the time of the study, and we assumed that scale-up occurred linearly through 2020. Finally, to produce analytical equations for the relevant measures, we tested regression models that only had terms up to degree 2, e.g. D^1 , D^2 , and not of higher orders, e.g., D^3 , D^4 .

In conclusion, our model of sexual transmissions of HIV in the United States indicates that a 25% reduction in incidence by 2020 can be achieved through attainment of multiple combinations of goals related to diagnosis and viral load suppression. Achieving the reduction will require a focus on getting highest risk groups tested early in the course of their infection and linking them to care. And it will require high rates of ART prescription soon after diagnosis and high, sustained adherence to ensure that most persons living with HIV achieve and maintain viral suppression. However, lesser success in achieving viral suppression may be offset by greater improvement in increasing the percentage of persons whose HIV is diagnosed. Health departments can measure their progress toward reducing incidence by monitoring local HIV surveillance data trends in CD4 count at diagnosis along with the proportion who have achieved viral suppression and determine where best to focus local programmatic efforts.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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All authors contributed to the writing of the article and approved the final version. All authors were equally involved in the analytical interpretation and analyses of numerical results. CG conducted the modeling. CG and YHC generated the data estimates for model parameterization. SLS and PGF developed the questions and interventions for analyses, and analyzed numerical results for policy implications. We acknowledge Dr. Irene Hall from the Centers for Disease Control and Prevention for her insightful comments and suggestions on the paper.

References

- Centers for Disease Control and Prevention. Monitoring selected national HIV prevention and care objectives by using HIV surveillance data—United States and 6 dependent areas, 2014. HIV Surveillance Supplemental Report. 2016; 21(4) [Accessed [October 2016]] <http://www.cdc.gov/hiv/library/reports/surveillance/>. Published July 2016.
- Song R, Hall HI, Green TA, Szwarcwald CL, Pantazis N. Using CD4 data to estimate HIV incidence, prevalence, and percent of undiagnosed infections in the United States. J Acquir Immune Defic Syndr. 2017 Jan 1; 74(1):3–9. [PubMed: 27509244]
- National HIV/AIDS Strategy for the United States. [Accessed 12-15-2011] The White House Office of National AIDS Policy. Jul. 2010 Available at <http://www.aids.gov/federal-resources/policies/national-hiv-aids-strategy/nhas.pdf>
- National HIV/AIDS Strategy for the United States: Updated to 2020. [Accessed 8-15-2015] The White House Office of National AIDS Policy. Jul. 2015 Available at <https://www.aids.gov/federal-resources/national-hiv-aids-strategy/nhas-update.pdf>
- Centers for Disease Control and Prevention. Monitoring selected national HIV prevention and care objectives by using HIV surveillance data—United States and 6 dependent areas—2012. HIV Surveillance Supplemental Report. 2013; 19(3) [Accessed September 2017] <http://www.cdc.gov/hiv/library/reports/surveillance/>. Published October 2014.
- Holtgrave DR, Greenwald R. A SWOT Analysis of the updated National HIV/AIDS Strategy for the U.S., 2015–2020. AIDS Behav. 2016 Jan; 20(1):1–6. [PubMed: 26370101]
- Gopalappa C, Farnham PG, Chen YH, Sansom SL. Progression and Transmission of HIV/AIDS (PATH 2.0): A new agent-based model to estimate HIV transmissions in the United States. Med Decis Making. 2017 Feb; 37(2):224–233. [PubMed: 27646567]
- Blower SM, Dowlatabadi H. Sensitivity and uncertainty analysis of complex models of disease transmission: an HIV model, as an example. International Statistical Review. 1994; 62(2):229–243.
- Lodi S, Phillips A, Touloumi G, Geskus R, Meyer L, Thiebaut R, et al. Time from human immunodeficiency virus seroconversion to reaching CD4+ cell count thresholds 200, 350, and 500 Cells/mm(3): assessment of need following changes in treatment guidelines. Clin Infect Dis. 2011 Oct; 53(8):817–825. [PubMed: 21921225]
- Gosavi, A. Simulation-based optimization: parametric optimization techniques and reinforcement learning. Boston: Kluwer Academic Publishers; 2003.
- Centers for Disease Control and Prevention. [Accessed [July 2017]] CDC Fact Sheet, Selected National HIV Prevention and Care Outcomes in the United States. Jul. 2017 <https://www.cdc.gov/hiv/pdf/library/factsheets/cdc-hiv-national-hiv-care-outcomes.pdf>
- Centers for Disease Control and Prevention. [Accessed [July 2017]] CDC Fact Sheet, HIV Incidence: Estimated Annual Infections in the U.S., 2008–2014 Overall and by Transmission Route. Feb. 2017 https://www.cdc.gov/nchhstp/newsroom/docs/factsheets/HIV-Incidence-Fact-Sheet_508.pdf
- Centers for Disease Control and Prevention. HIV Surveillance Report. 2015; 27 [Accessed [July 2017]] <http://www.cdc.gov/hiv/library/reports/hiv-surveillance.html>. Published November 2016.
- Centers for Disease Control and Prevention. Monitoring selected national HIV prevention and care objectives by using HIV surveillance data—United States and 6 dependent areas, 2014. HIV Surveillance Supplemental Report. 2016; 21(4) [Accessed [July 2017]] <http://www.cdc.gov/hiv/library/reports/surveillance/>. Published July 2016.
- Bonacchi RA, Holtgrave DR. Simplified estimates of HIV incidence and transmission rates for the USA, 2008–2012. AIDS. 2016 Jan; 30(2):332–333. [PubMed: 26691552]

16. Shah M, Perry A, Risher K, Kapoor S, Grey J, Sharma A, et al. Effect of the US National HIV/AIDS Strategy targets for improved HIV care engagement: a modelling study. *Lancet HIV*. 2016 Mar 01; 3(3):e140–6. [PubMed: 26939737]

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Figure 1.

Combinations of percentages of persons living with HIV with diagnosed infection (x-axis) and persons living with diagnosed HIV who have viral load suppression (VLS) (y-axis) that achieve, by 2020, the national HIV prevention goals of a 25% reduction in annual HIV infections (solid line), a 25% reduction in annual diagnoses (dotted line), and associated CD4 counts at diagnosis (shaded contours).

*The percentage of those linked to care within 1 month of diagnosis is fixed at 85%.

Note: At basecase, i.e., year 2010, 85% were diagnosed and 33% among diagnosed had viral suppression

Figure 2.

Reductions in annual HIV infections (shaded contours) and reductions in annual diagnoses (dotted contours) achieved, by 2020, under different combinations of percentages of persons living with HIV with diagnosed infection (x-axis) and persons living with diagnosed HIV who have viral load suppression (VLS) (y-axis).

Note: At basecase, i.e., year 2010, 85% were diagnosed and 33% among diagnosed had viral suppression

Annual HIV infections and HIV diagnoses by 2020 under different assumptions about percentages of persons living with HIV with diagnosed infection, persons with newly diagnosed HIV who are linked to care within one month of diagnosis, and persons living with diagnosed HIV who have viral load suppression.

Table 1

Year	2010	2020	2020	2020	2020	2020
Scenarios	Base case	Scenario 1 (A)	Scenario 2 (B)	Scenario 3 (D)	Scenario 4 (C)	
Diagnosed among PLWH	85%	85%	90%	85%	90%	
Linked to care in 1 month among newly diagnosed	82%	85%	85%	85%	85%	
Viral suppression among diagnosed ^a	33% (NA, NA)	68% (63, 71)	59% (54, 62)	78% (72, 83)	81% (77, 84)	
Annual number of HIV infections ^b	42,380	31,703	31,725	27,744	21,940	
Annual number of HIV diagnoses ^b	41,868	34,313	40,300	31,271	31,511	
Reduction in annual infections ^a	reference	25% (NA,NA)	25% (NA,NA)	35% (33, 37)	48% (48, 49)	
Reduction in annual diagnoses ^a	reference	18% (16, 19)	4% (3, 4)	25% (NA,NA)	25% (NA,NA)	
Median CD4 count at diagnosis		372 (348, 397)	462 (449, 477)	352 (321, 381)	433 (417, 449)	
Median time from infection to diagnosis		3.8 (4.2, 3.3)	2.0 (2.2, 1.7)	4.2 (4.9, 3.6)	2.5 (2.9, 2.2)	

^aMedian and, in parentheses, 10th and 90th percentile values.

^bOnly persons infected through sexual transmissions

Table 2

Combinations of percentages of persons living with HIV with diagnosed infection and persons living with diagnosed HIV who have viral load suppression (VLS) to achieve 0%, 10%, 25%, 40% and 50% reductions in annual HIV infections by 2020.

Percent of PLWH with diagnosed infection	Percent with viral suppression among persons with diagnosed HIV for x% reduction in new infections			
	x=0%	x=10%	x=25%	x=50%
85%	42%	53%	68%	94%
90%	34%	44%	59%	83%

* The percentage of those linked to care within 1 month of diagnosis is fixed at 85%.