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Optimizing HIV Partner Services for Gay, Bisexual and Other Men Who Have Sex with Men Previously Diagnosed with HIV: A Modeling Study

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Abstract

Background: HIV Partner Services (HIV-PS) is a vital strategy for identifying and linking individuals to treatment and prevention, however, its population-level impact has been limited. This study investigated the potential impact of expanding HIV-PS to include previously diagnosed individuals and a broader sexual partner network in reducing HIV incidence among gay, bisexual, and other men who have sex with men (GBMSM).

Methods: Stochastic network models were employed to simulate HIV and bacterial sexually transmitted infection transmission within male same-sex partnerships in Atlanta. Two primary interventions were examined: prioritizing people with previously diagnosed HIV who were out-of-care (PWDH-OOC) in routine HIV-PS and expanding partner elicitation to include partners of HIV-positive partners of index cases. We quantified how modifications to HIV-PS cascade steps under these interventions would impact HIV incidence among GBMSM.

Results: Expanded partner elicitation modestly increased the pool of partners eligible for linkage to transmission-disrupting services, with minimal impact on HIV incidence. In contrast, including PWDH-OOC led to a tenfold increase in both index-case and partner pools. However, substantial reductions in HIV incidence required enhancements to other HIV-PS steps, particularly in partner identification and anti-retroviral therapy (ART) reengagement for PWDH-OOC. Prioritizing ART reengagement for PWDH-OOC, alongside optimized HIV-PS, resulted in up to 63% of HIV infections being averted.

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CONTRIBUTIONS

UO designed the study, programmed the model, conducted the analyses, and wrote the manuscript. ALG and KMM supported in programming the model and conducting the analyses. CL and KPD provided key input in model parameterization and structure, and critically edited the manuscript. SMJ designed the study and supported in writing the manuscript.

DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention or other represented institutions.

CONFLICTS OF INTEREST

None.

Conclusion: Our study highlights the potential of strategic improvements to HIV-PS for accelerating HIV incidence reduction among GBMSM. Synergistic optimization of HIV-PS, along with prioritizing ART reengagement for previously diagnosed individuals, will be essential for achieving substantial reductions in HIV incidence.

SHORT SUMMARY

Stochastic network models showed that expanding HIV partner services to routinely include out-of-care individuals with previously diagnosed HIV increased engagement, but substantial HIV incidence reductions required better ART reengagement.

Keywords

HIV partner services; Gay and Bisexual Men; Mathematical models

INTRODUCTION

HIV remains a significant global health challenge, demanding innovative prevention approaches and more effective use of existing strategies to reduce incidence among priority populations such as gay, bisexual, and other men who have sex with men (GBMSM).¹ In the United States (US), HIV Partner Services (HIV-PS) is an established public health strategy², designed to facilitate treatment referrals for individuals diagnosed with HIV and link their sexual partners to diagnosis, treatment and preventive services.^{3,4} While HIV-PS has demonstrated public health benefits, including timely diagnosis and treatment for infected individuals, transmission chain disruption through contact tracing, and targeted linkage to preventative measures like HIV pre-exposure prophylaxis (PrEP)⁵, its full potential remains unrealized. Enhancing the effectiveness of HIV-PS in identifying undiagnosed HIV infections and reaching those at increased risk in GBMSM populations is a critical priority for public health. With further optimization, HIV-PS could serve as an efficient strategy to achieve these goals.⁶⁻⁸

Traditional HIV-PS primarily targets newly diagnosed individuals, aiming to quickly link them to medical care, while also identifying their sexual partners for rapid testing and care to prevent onward transmission.⁹ However, this approach often overlooks sexually active individuals with a previous HIV diagnosis (PWDH) who are inconsistently engaged in care. This group, identified as contributing one of the highest proportions of onward HIV transmissions¹⁰⁻¹², can transmit the virus during periods when detectable viral loads and unprotected sex with at-risk partners coincide.^{13,14} Although partners of PWDH are often perceived to be at lower risk due to expected behavioral changes and antiretroviral therapy (ART) use¹⁵⁻¹⁷, variability in the adoption and persistence of these behaviors, coupled with inconsistent ART adherence and engagement in care, leaves partners vulnerable to HIV acquisition.^{13,14,18}

Additionally, the changing dynamics of sexual partnerships in today's digitally connected era have reshaped sexual networks, presenting challenges for traditional HIV-PS, which targets only named partners of index cases.^{4,19} This approach potentially misses opportunities to engage additional individuals indirectly connected to the index case through

their named sexual partners (i.e., sexual partners of the partners named by index cases). An implementation question therefore arises as to whether targeting additional waves of partners would yield substantial reductions in HIV incidence compared to focusing solely on immediate named partners.

These gaps likely contribute to the limited population-level impact of HIV-PS on reducing HIV incidence among US GBMSM.²⁰ Research indicates that HIV-PS identifies less than 5% of new HIV diagnoses in the US²¹, and recent modeling suggests that removing HIV-PS, as currently implemented, would only minimally affect cumulative incidence among GBMSM.⁸ While maximally optimizing steps within the HIV-PS cascade theoretically reduced incidence, realistic improvements only yielded modest results.⁸ The model emphasized that the limited number of newly diagnosed index cases and their partners accessing HIV transmission-interrupting services (ART and PrEP) through traditional HIV-PS is central to this limited impact. However, the study did not evaluate the potential benefits of including previously diagnosed individuals as index cases, or engaging partners of the index case's partners in these services.

In this study, we used a stochastic network model of HIV transmission among GBMSM in Atlanta to assess the impact of expanding HIV-PS by incorporating out-of-care PWDH (as an index-pool expansion strategy) and partners of the index case's named partners (as a partner-pool expansion strategy) on HIV incidence among GBMSM. We aimed to quantify how modifications to both upstream (working with index patients) and downstream (working with partners) HIV-PS cascade steps collectively influence HIV incidence reduction among GBMSM.

METHODS

Study Design.

We employed a stochastic network model to simulate HIV, *Neisseria gonorrhoeae* (NG), and *Chlamydia trachomatis* (CT) transmission among GBMSM in the Atlanta metropolitan statistical area, utilizing the EpiModel software platform.²² This study builds upon our prior research into partner-based strategies for HIV and bacterial sexually transmitted infections (STI)⁸, and model specifics are detailed in the Appendix. The model code can be accessed on GitHub (<https://github.com/EpiModel/PartnerServiceYr3>).²³ We modeled main, casual, and one-time sexual partnerships among Black, Hispanic, and White GBMSM, aged 15 to 65 years in Atlanta. Our initial model comprised 100,000 GBMSM, representing the estimated GBMSM population size in Atlanta, with an open structure allowing for new arrivals (at sexual debut) and departures (from mortality or sexual activity cessation). All model scenarios were based on parameters from 2019, prior to COVID-19 disruptions to services, specifically those used to operationalize and calibrate measures of disease prevalence, HIV and STD risk behaviors, and progression^{9,24}

Core Model and Data Sources.

We adapted the HIV-PS framework from our earlier study.⁸ The starting network was constructed using network size and demographic attributes, with sexual partnerships

formation and dissolution between nodes estimated using temporal exponential random graph models at each timestep.²⁵ Sexual risk behaviors (e.g. act frequency, positioning, and condom use) were predicted for each partnership using generalized linear models and ARTnet study data.²⁶ ARTnet was a 2017–2019 online cross-sectional study of nearly 5,000 US GBMSM, collecting data on mixing patterns, partnership durations and other sexual network features across 16,000 partnerships. As the first US egocentric network study of MSM, its data have been instrumental in parameterizing dyadic measures for sexual network models of US GBMSM.^{8,27,28} HIV, NG, and CT transmission within discordant partnerships were simulated separately, incorporating disease progression, natural history, and recovery (for NG and CT infections only). Parameters for HIV/NG/CT transmission, diagnosis, and treatment were derived from secondary data (see Appendix) and public health surveillance data.^{8,23,26}

Existing HIV-PS (or Reference) Model.

In the reference model, representing the existing HIV-PS framework where partner services are primarily offered to newly diagnosed individuals, dual pathways to HIV services were modeled: individuals could access services either independently through an individual-based pathway or through HIV-PS via the partner-based pathway. Parameters governing access through the individual-based pathway were calibrated to match the 2019 Georgia Department of Public Health (GDPH) surveillance estimates for HIV testing and care continuum (linkage, engagement, retention, and viral suppression) among GBMSM.²⁹ PrEP-related parameters were based on composite estimates of PrEP coverage and persistence among GBMSM in Georgia for same year.³⁰ Individuals cycled on and off ART or PrEP at rates calibrated to achieve 61% HIV viral suppression prevalence and 30% PrEP coverage (Appendix)²⁹, with race-stratified parameters included to reflect the observed disparities in engagement in these services across racial groups (Appendix).²⁹

Access to HIV services through HIV-PS was limited to newly diagnosed individuals and their partners. Similar to our earlier study⁸, this pathway was represented in the model in four steps: 1) newly diagnosed GBMSM (“ND-indexes”) are identified and consent to partner services; 2) their sexual partners within the past year are elicited and identified (“Wave-1 partners”); 3) identified wave-1 partners are screened for HIV; and 4) screened partners are linked to ART or PrEP based on their HIV status. Steps 1–2 were termed “upstream,” while steps 3–4 were “downstream” HIV-PS cascade steps.⁸

Enhanced HIV-PS (or Intervention) Models.

Two interventions representing enhancements to the existing HIV-PS framework were investigated. In the first, we explored expanding HIV-PS to include individuals previously diagnosed but disengaged from care (the index-pool expansion strategy). To simulate this, we introduced periodic retesting for out-of-care persons with prior HIV diagnoses, estimating the frequency of repeat testing as a function of the time since their initial HIV diagnosis based on an analysis of the 2020 American Men’s Internet Survey (AMIS)³¹ data. PWDH-OOC retested for HIV became eligible for HIV-PS and were included as index cases (“PD-indexes”) in Step 1 of the cascade. In the base scenario for this intervention model, we assumed a 64% HIV-PS participation among PD-indexes, consistent with the 2017 CDC

report on HIV-PS acceptance of HIV-PS among previously diagnosed individuals (Table 1).³² Similar to the reference model, ART reengagement (for both PD-indexes and all out-of-care HIV-positive partners) and PrEP initiation (for HIV-negative partners) via HIV-PS were conservatively set at zero, reflecting uptake of these services through HIV-PS among Atlanta GBMSM.⁸ A variant scenario explored the impact of improved ART reengagement within HIV-PS. Re-engaged individuals were assumed to have the same probability of discontinuing ART as all other individuals in the network accessing care. This assumption was made under the expectation that re-engagement would not lead to substantial changes in adherence behavior, and it was considered a reasonable upper bound for assessing the potential impact of re-engagement.

In the second intervention model, we broadened partner elicitation to include sexual partners of HIV-positive Wave-1 partners (termed “Wave-2” partners), integrating this group as a novel fifth step in the HIV-PS cascade. Identified Wave-2 partners were then evaluated similarly to identified Wave-1 partners, being screened for HIV and referred to ART or PrEP as appropriate, with parameters for Wave-2 partner elicitation, identification, and services uptake mirroring those of Wave-1 partners.

Model Scenarios.

Incremental enhancements to the HIV-PS cascade steps were simulated for the reference and intervention models.⁸ For the upstream steps, we increased index-case participation and identification probabilities from baseline values of 67% for ND-indexes and 64% for PD-indexes up to full participation (100%) among all eligible index cases. We also explored improvements in partner elicitation and identification probabilities, with increases of 50% and 100% over baseline. Downstream steps enhancements assessed increases in partner HIV screening uptake, PrEP initiation for HIV-negative partners, ART linkage for newly diagnosed partners, and ART reengagement for PD-indexes and previously diagnosed partners not in care, with probabilities ranging from 0% to 100%. In each enhancement scenario, all parameters were maintained at baseline values, except for the evaluated cascade step’s parameter. Additionally, we simulated scenarios with maximum joint improvements across all cascade steps to assess the impacts of a fully optimized HIV-PS.

Model Calibration and Outcomes.

We calibrated our reference model following the approach outlined in our prior publication, aligning it with local HIV/STI surveillance data from 2019 (see Appendix).⁸ After calibration, we conducted 320 simulations for each scenario across the three main models (reference, intervention model 1, and intervention model 2) over a 10-year horizon, summarizing outcomes using medians and 95% simulation intervals (SI).

Outcomes assessed included epidemiological indicators, HIV prevention and care continuum measures, and HIV-PS cascade-related metrics. Epidemiological outcomes focused on HIV incidence rates (IR), defined as new infections during the final year of the intervention per 100 person-years, along with cumulative incidence over the entire 10-year period. We also calculated the number and percent of infections averted (NIA and PIA, respectively) in each scenario compared to the baseline scenario (existing HIV-PS model where partner services

are focused on newly diagnosed index cases only). In the analysis where HIV-PS cascade steps were maximally optimized, we determined the numbers needed to treat (NNT), representing the number of ND-indexes and PD-indexes required to engage in HIV-PS to prevent one new HIV infection.

RESULTS

In our calibrated base (or reference) model representing existing HIV-PS, and focused solely on newly diagnosed GBMSM, we estimated 8196 (95% SI: 7951, 8509) new HIV infections among the 100,000 GBMSM in the network over 10 years, with a final year (year-10) HIV IR of 0.82 (95% SI: 0.75, 0.89) per 100 person-years (Supplemental Table 1-A). Notably, our findings highlight that substantial reductions in HIV incidence were only achieved when HIV-PS efforts included ART reengagement for previously diagnosed GBMSM who were out-of-care. Incorporating these individuals into the HIV-PS index-case pool had minimal impact on cumulative HIV incidence or year-10 IR in most single cascade step improvement scenarios (maximum PIA achieved = 2%), unless ART reengagement was also improved within the HIV-PS context (Table 2). In scenarios where ART reengagement was enhanced, the percentage of infections averted increased substantially, from 8% with a 10% increase in ART reengagement probability for PD-indexes to a maximum of 44% with 100% reengagement. Similarly, year-10 IR also decreased substantially in these scenarios, from 0.82 (base scenario) to 0.40 (95% SI: 0.36, 0.45) with 100% ART reengagement. In contrast, direct expansion of the HIV-PS partner pool through incorporation of Wave-2 partners did not meaningfully alter cumulative HIV incidence or year-10 IR in any of the single step improvement scenarios (maximum PIA achieved = 0.4%, Supplemental Table 3-A).

Results presented in Supplemental Tables 2-A through 2-C illustrate why single step changes in the HIV-PS cascade, except those involving ART reengagement for PD-indexes, resulted in minimal reductions in HIV incidence. The inclusion of PD-indexes in HIV-PS significantly expanded the pool of eligible and engaged index-cases, increasing it over ten-fold from a median of 663 eligible and 441 identified index-cases (Supplemental Table 1-C) to 7066 eligible and 4537 identified index-cases (Supplemental Table 2-B). This extension indirectly raised the pool of partners eligible for partner services from 781 (base model) to 7565 (intervention model). Despite this increase, only a small fraction of this enlarged partner pool engaged in downstream HIV transmission-disrupting services through HIV-PS. Of 7565 eligible partners in the intervention model, only 803 were identified (Supplemental Table 2-B). Among these, 351 had a prior HIV diagnosis, while 452 had a prior HIV-negative or unknown status. Supplemental Table 2-C shows that only a subset of this group progressed further: specifically, out of 452 HIV-negative/unknown partners, only 178 received HIV screening via partner services, resulting in 32 new HIV diagnoses. Of these 32 newly diagnosed partners, only 13 initiated ART through HIV-PS. Limited ART reengagement and PrEP initiation through HIV-PS meant that none of the 351 identified partners with prior HIV-positive status who might have been out of care, or the 146 screened partners who tested HIV-negative who might not have been on PrEP, initiated these transmission-disrupting strategies. This shift from a large pool of eligible individuals to a smaller group available for transmission-disrupting services, and the further

reduction to a much smaller group directly receiving these services within the HIV-PS framework explains why expanding the index case pool without addressing engagement in HIV disrupting services (particularly ART reengagement) did not lead to substantial population-level impacts.

Table 3 presents the results of optimized scale-up scenarios where upstream and downstream HIV-PS cascade steps are jointly maximized. Compared to the reference model focusing solely on newly diagnosed GBMSM for HIV-PS, maximizing all cascade steps resulted in a 9.3% (95% SI: 4.8%, 13.0%) reduction in cumulative HIV incidence (PIA). Including Wave-2 partners of newly diagnosed index cases in HIV-PS did not appreciably decrease HIV incidence beyond that obtained in the base/reference model (maximum PIA: 11.3% [95% SI: 6.8%, 15.4%]). In the intervention model including out-of-care previously diagnosed GBMSM in HIV-PS, maximizing all cascade steps showed more significant improvements in HIV incidence reduction. Without improvements to ART reengagement for PD-indexes, maximal optimization of HIV-PS cascade steps yielded 34.5% PIA (95% SI: 30.8%, 37.4%). Maximizing ART reengagement for PD-indexes within the HIV-PS framework nearly doubled this impact, achieving a maximum PIA of 63.1% (95% SI: 60.7%, 65.2%) when all cascade steps were maximized. Trends in year-10 IR reflected similar improvements, with the lowest IR (0.26 [95% SI: 0.22, 0.30]) observed in the intervention model incorporating previously diagnosed individuals in HIV-PS and maximizing ART reengagement for all eligible within partner services (Figure 1C).

Table 3 also shows the estimated NNT to achieve reductions in HIV incidence under each model and scenario. In the reference model, maximal optimization of all HIV-PS cascade steps had the lowest NNT at 9 (95% SI: 6, 18), indicating that engaging nine index-cases in HIV-PS would avert 1 new HIV infection if all HIV-PS cascade steps are maximally improved. NNT varied widely across the intervention models, ranging from 19 to 229 with joint maximal optimization of all HIV-PS cascade steps when out-of-care PWDH were included in HIV-PS without improving ART reengagement for PD-indexes. However, NNT fell to 4 (95% SI: 4, 5) when reengagement in ART for PD-indexes was also maximized.

Figure 2 shows the relationship between improved index case and partner participation in HIV partner services and the percentage of new HIV infections averted (PIA) over 10 years. Improved participation had minimal impact on PIA when involving only index cases and their immediate partners (2A) or including wave-2 partners (2D). However, PIA increased significantly when previously diagnosed individuals were included (2B), reaching up to 60% when ART reengagement for these individuals was also maximized (2C).

DISCUSSION

In the US, HIV partner services is instrumental for linking persons diagnosed with HIV to care while facilitating testing, prevention, and care services for their sexual partners,^{4,6,19,21} However, the population-level impact of HIV-PS on HIV incidence may remain limited without major enhancements.⁸ In this study, we evaluated the potential benefits of enhancing the HIV-PS framework among GBMSM by including out-of-care individuals with diagnosed HIV (PWDH) as a priority population in HIV-PS and extending partner elicitation beyond

index case's ("Wave-1") named partners. While extending partner elicitation had minimal impact on the partner pool, incorporating PWDH who were out-of-care substantially increased both index-case and partner pools, thus broadening the participant base eligible for downstream transmission-disrupting services. However, translating this participant pool expansion into significant HIV incidence reduction required further enhancements to ART and PrEP delivery within HIV-PS. Calls to prioritize reengagement of out-of-care PWDH in HIV care and prevention services, including HIV-PS, are not new and have been made over the past decade.^{33–35} While prior studies have been largely descriptive or qualitative, our study quantifies the potential impact of incorporating out-of-care PWDH into HIV-PS, particularly when paired with targeted improvements in ART reengagement. By doing so, we provide actionable insights for operationalizing these enhancements within HIV-PS systems.

Targeted intervention approaches maximize benefits by directing resources to those most in need for HIV-transmission disrupting services.^{36,37} In our study, prioritizing out-of-care PWDH alongside newly diagnosed HIV cases for HIV-PS significantly expanded the pool of eligible index-case and partner pools available for these services, suggesting this enhancement may be an effective approach to reaching a wider segment of the target population with HIV transmission-disrupting services compared to current HIV-PS strategies. Additionally, it fosters a collaborative approach to HIV control by emphasizing the importance of sustained engagement with PWDH to achieve meaningful population-level reductions in HIV incidence.¹¹

CDC's annual HIV testing data indicating that about half of all positive CDC-funded HIV tests in the US are among previously diagnosed individuals support the feasibility of prioritizing PWDH in HIV-PS.³⁸ Retesting PWDH, which typically occurs during transitions in medical care, could serve as a trigger for routine linkage to HIV-PS for these individuals, similar to current practice for newly diagnosed cases. Similarly, focusing on individuals with new STI diagnoses is a practical strategy, as they are already engaged with healthcare and may have higher transmission risk behaviors. By integrating HIV-PS into STI care services, health departments could streamline reengagement efforts, reduce barriers, and enhance outreach to individuals at heightened risk of onward transmission. Other practical approaches include pharmacy-based strategies, where lapsed ART prescriptions help identify and reengage out-of-care PWDH.³⁹ Emergency departments and urgent care settings, where many disengaged individuals seek care, also offer key opportunities through automated HIV-PS and ART reengagement prompts to facilitate timely linkage. These practical approaches circumvent challenges related to data accuracy and timeliness experienced by prior data-led efforts to reengage out-of-care PWDH^{40–42}, as it leverages individuals already in contact with the healthcare system. Other actionable steps include expanding access to low-barrier HIV care, offering incentives for out-of-care PWDH to reengage, and potentially reserving slots for out-of-care PWDH at local public health programs.^{43,44} Such measures could enhance participation and reengagement in HIV care.

While expanding reach to a broader segment of the target population holds advantages, enhancing the delivery of and engagement in HIV diagnosis, treatment and prevention within the HIV-PS framework is crucial to achieving significant population-level reductions

in HIV incidence, especially in the US South. Our previous study highlighted the stark drop-off from the number of GBMSM engaged in upstream HIV-PS cascade steps to those benefiting from downstream services such as ART and PrEP, which directly mitigate HIV incidence, as a key limitation of traditional HIV-PS impact.⁸ This study underscores that expanding the pool of HIV-PS participants available for these downstream services through targeted program expansions, such as prioritizing PWDH in HIV-PS, would similarly fail to tangibly impact HIV incidence if not coupled with enhanced engagement in these services within HIV-PS, particularly ART reengagement for PWDH. Addressing PWDH reengagement in ART within HIV-PS was projected to substantially increase the effectiveness of HIV incidence reduction efforts and enhance the overall efficiency of HIV-PS as a tool for HIV control. Achieving increased inclusion of PWDH into local HIV prevention efforts may involve using all instances of HIV retesting as a trigger for initiating partner services, collaborating with community organizations to encourage participation in partners services for PWDH, and utilizing existing surveillance systems to re-engage PWDH to both ART and HIV-PS for partner elicitation and linkage to relevant services. Introducing secure telemedicine in HIV-PS also holds promise for supporting re-engagement among PWDH, particularly those facing healthcare system fatigue or barriers to engaging with in-person services, potentially improving their HIV-PS participation rates.

Several limitations affect the interpretation of our findings. First, the parameters used in the stochastic model were derived from pre-COVID-19 surveillance data and empirical research, neglecting the impact of the COVID-19 pandemic on both sexual behaviors among GBMSM and HIV-related healthcare disruptions.^{45,46} However, current evidence suggests that any such impacts may be minimal, as behavioral and service parameters have largely returned to pre-pandemic levels.⁴⁷ Second, our model assumed consistent behavioral responses over time and did not account for potential changes in risk behaviors following HIV diagnosis.^{14–16,48} Addressing these nuances is crucial for accurately predicting outcomes post-HIV-PS participation among GBMSM, yet empirical data in this rapidly evolving landscape, marked by increasing PrEP and ART use, remain limited. Third, our study focused solely on Black, White, and Hispanic racial groups, excluding other races and ethnicities, which limits the generalizability of our findings beyond these racial groups. Finally, our study focused on Atlanta, a metropolitan area with unique population demographics, HIV prevalence, and HIV-PS system. Extrapolating our findings to cities, whether with more or less established HIV-PS systems, necessitates careful consideration of local contexts, population dynamics, and healthcare infrastructure variations.

Conclusions.

Our study demonstrates that expanding the HIV-PS participant pool to include previously diagnosed GBMSM who are not engaged in care may enhance the overall impact and efficiency of HIV-PS. However, realizing substantial benefits requires concurrent improvements in linking GBMSM to essential HIV ART and PrEP within the HIV-PS framework. Prioritizing ART reengagement for previously diagnosed individuals who have disengaged from HIV medical care is crucial and can significantly bolster existing HIV-PS systems where such linkages are deficient. With these enhancements, HIV-PS can emerge as

a pivotal strategy for preventing new HIV infections and achieving HIV prevention goals in the US.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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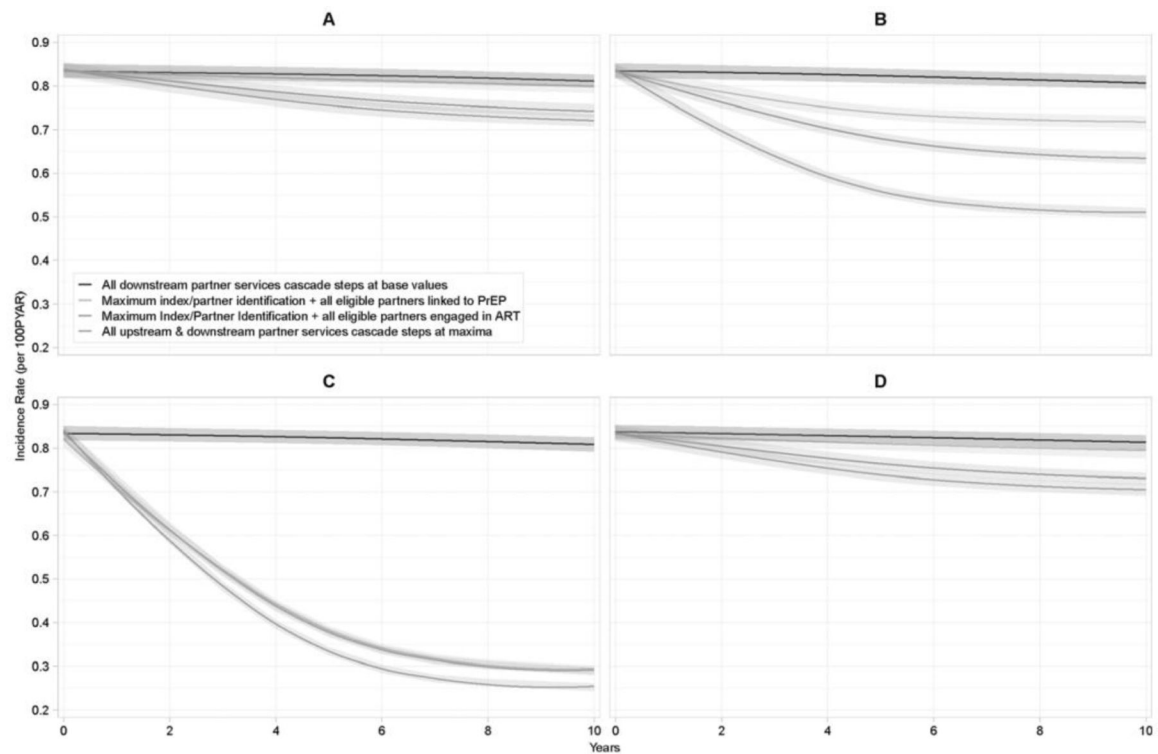


Figure 1.

Estimated HIV Incidence Rate Over a 10-year Period

Panel shows estimated HIV incidence rates (per 100 person-years at risk [PYAR]) among GBMSM across a 10-year period when HIV partner services are focused on: **(A)** newly diagnosed index cases and their named partners only, **(B)** both newly and previously diagnosed index cases (and their named partners), but without improving ART reengagement among previously diagnosed index cases within the HIV partner services framework, **(C)** both newly and previously diagnosed index cases (and their named partners), with improvement in ART reengagement among previously diagnosed persons within the partner services framework, and **(D)** newly diagnosed index cases, their named partners and named wave-2 Partners.

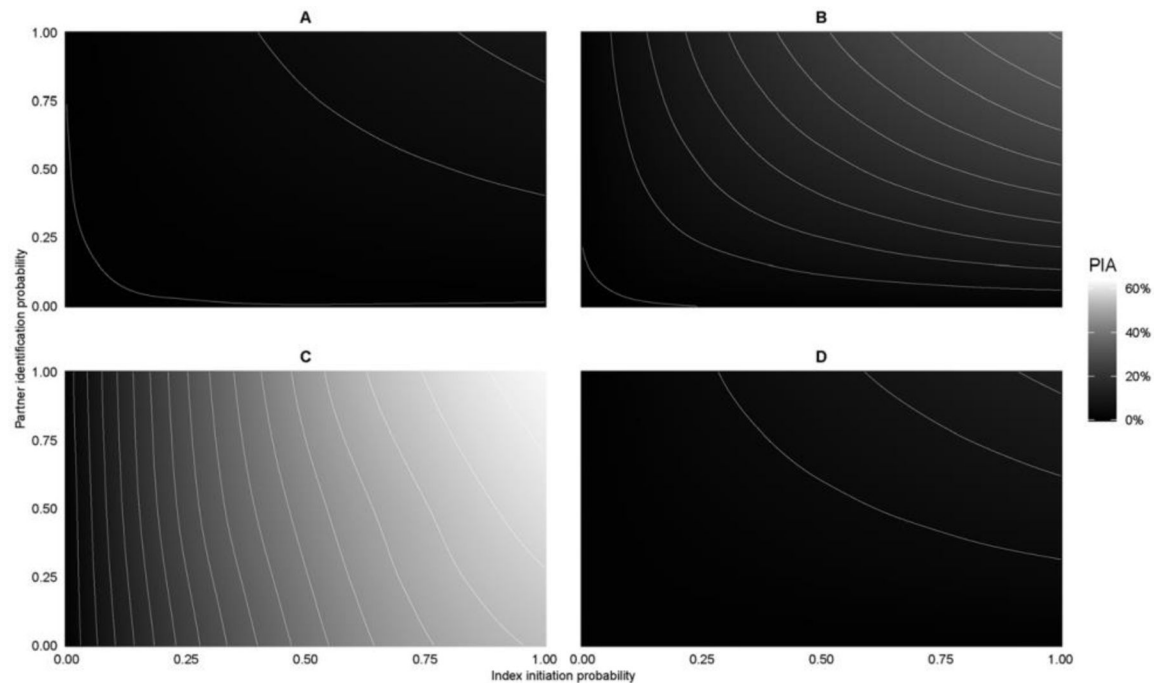


Figure 2.

Relationship between improved index case and partner participation in HIV partner services, and percent of new HIV infections averted (PIA) over 10 years.

Panel shows how improvements in index case and partner participation in partner services impact the percent of HIV infections averted (PIA) in scenarios where HIV partner services are focused on: **(A)** newly diagnosed index cases and their named partners only, **(B)** both newly and previously diagnosed index cases (and their named partners), but without improving ART reengagement among previously diagnosed index cases within the HIV partner services framework, **(C)** both newly and previously diagnosed index cases (and their named partners), with improvement in ART reengagement among previously diagnosed persons within the partner services framework, and **(D)** newly diagnosed index cases, their named partners and named wave-2 Partners.

Improved index and/or partner participation in HIV partner services had minimal impact on PIA in scenarios where only index cases and their partners alone (2A) or inclusion of wave-2 partners (2D) were the only improvements made. Improvements in index case and partner participation were associated with increased PIA when previously diagnosed individuals were also incorporated in HIV partner services alongside newly diagnosed cases (2B), reaching over 60% when concurrent improvements to ART reengagements for previously diagnosed persons were also made within partner services framework (2C).

HIV Partner Services Cascade: Model Parameters and Sources

Table 1.

Parameter	Description	Base Model Parameter	Sources
Index Network Degree	Minimum number of cumulative partners in window before triggering partner services	1	Assumed
HIV testing rate			
General population	Testing rate among persons not known to have HIV infection	Varies by race	CDC HIV Surveillance
Previously diagnosed	Testing rate among persons previously diagnosed with HIV	Dependent on time since HIV diagnoses	2020 American Men's Internet Survey (Analysis)
Index initiation probability			
Newly diagnosed	Probability that an index patient offered and accept partner services	0.667	2018 CDC PS Report ⁴⁹
Previously diagnosed		0.640	2017 CDC HIV testing Report ³²
Index Partnership Window			
Main Partners		52	
Casual Partners	Number of weeks in the past that a partnership of each type qualifies for partner elicitation	52	PS Recommendations ⁹
One-Time Partners ^a		52	
Partner Identification			
Partners: Index Ratio	Number of identified partners per index case	0.432	
Casual to Main Scalar	Odds ratio for the probability identification of casual partners to that of main partners	0.50	2018 CDC PS Report
One-Time to Main Scalar	Odds ratio for the probability identification of one-time partners to that of main partners	0.25	
Partner HIV Screening	Probability of completing HIV screening for partners identified and reached	39.4%	2018 CDC PS Report
Partner PrEP Linkage	Probability of a partner who screened HIV- and with current indications starting PrEP	0	Assumed
Partner Care Linkage	Probability of a partner who newly screened HIV+ and not currently in care will start ART	38.7%	2018 CDC PS Report
Partner ART Reengagement	Probability of a partner who previously screened HIV+ and previously in ART care will restart ART	0	Assumed

Abbreviations: ART = anti-retroviral therapy; PrEP = pre-exposure prophylaxis for HIV; PS = partner services

^aPartners with whom index case had a single sexual encounter

Table 2.

HIV Partner Services Expansion to Include Both Newly and Previously Diagnosed HIV Index Cases: Impact of Single Cascade Step Improvements on HIV Epidemiological Outcomes Among Atlanta Gay, Bisexual, and Other Men who Have Sex with Men (GBMSM)

Scenarios	Incidence Rate at Year 10		Cumulative Incidence Over 10 Years		Number of Infections Averted Over 10 Years ^c		Percent Infections Averted Over 10 Years ^c	
	Median (95% SI)		Median (95% SI)		Median (95% SI)		Median (95% SI)	
Base	0.82 (0.76, 0.89)		8195 (7919, 8479)		0		0.0 (0.0, 0.0)	
Index Initiation Probability								
70%	0.82 (0.75, 0.88)		8143 (7886, 8477)		35 (-402, 408)		0.4 (-5.0, 4.9)	
100%	0.82 (0.76, 0.89)		8162 (7898, 8445)		6 (-340, 418)		0.1 (-4.3, 5.0)	
Partner Identification Probability								
Base x1.5	0.82 (0.75, 0.89)		8170 (7880, 8464)		12 (-353, 403)		0.1 (-4.5, 4.8)	
100% (All Eligible Partners)	0.80 (0.74, 0.87)		8012 (7755, 8276)		173 (-187, 563)		2.1 (-2.3, 6.8)	
Partner HIV Screening Probability								
Base x2.0	0.82 (0.75, 0.90)		8156 (7860, 8415)		38 (-351, 464)		0.5 (-4.4, 5.5)	
100% (All Eligible Partners)	0.82 (0.76, 0.89)		8150 (7854, 8402)		20 (-360, 423)		0.2 (-4.4, 5.1)	
Partner PrEP Linkage Probability								
50%	0.82 (0.75, 0.90)		8176 (7876, 8439)		18 (-390, 408)		0.2 (-4.9, 4.9)	
100% (All Eligible Partners)	0.82 (0.75, 0.89)		8142 (7826, 8404)		54 (-342, 454)		0.7 (-4.3, 5.5)	
Partner ART Linkage Probability								
Base x1.5	0.82 (0.75, 0.89)		8187 (7931, 8483)		2 (-419, 366)		0.0 (-5.3, 4.4)	
100% (All Eligible Partners)	0.82 (0.75, 0.90)		8179 (7945, 8439)		2 (-345, 391)		0.0 (-4.3, 4.6)	
Partner ART Reengagement Probability ^a								
10%	0.82 (0.75, 0.90)		8157 (7902, 8469)		14 (-369, 417)		0.2 (-4.6, 5.0)	
25%	0.82 (0.75, 0.89)		8149 (7887, 8409)		46 (-332, 426)		0.6 (-4.1, 5.0)	
50%	0.81 (0.74, 0.88)		8092 (7842, 8400)		105 (-332, 440)		1.3 (-4.2, 5.3)	
75%	0.81 (0.74, 0.88)		8065 (7795, 8328)		144 (-246, 567)		1.8 (-3.0, 6.7)	
100% (All Eligible Partners)	0.80 (0.73, 0.87)		8007 (7718, 8296)		166 (-227, 604)		2.0 (-2.8, 7.2)	
Index ART Reengagement Probability ^b								
10%	0.73 (0.66, 0.81)		7520 (7222, 7774)		676 (282, 1105)		8.2 (3.5, 13.4)	
25%	0.64 (0.58, 0.71)		6702 (6447, 6970)		1480 (1065, 1880)		18.1 (13.3, 22.2)	

Scenarios	Incidence Rate at Year 10	Cumulative Incidence Over 10 Years	Number of Infections Averted Over 10 Years ^c	Percent Infections Averted Over 10 Years ^c
	Median (95% SI)	Median (95% SI)	Median (95% SI)	Median (95% SI)
50%	0.53 (0.47, 0.60)	5764 (5526, 6015)	2426 (2041, 2839)	29.6 (25.6, 33.7)
75%	0.46 (0.41, 0.52)	5076 (4841, 5292)	3114 (2772, 3476)	38.1 (34.9, 41.8)
100% (All Eligible PD-indexes)	0.40 (0.36, 0.45)	4542 (4364, 4796)	3645 (3305, 3964)	44.4 (41.1, 47.1)

Abbreviations: ART = anti-retroviral therapy; PrEP = pre-exposure prophylaxis for HIV; PD-indexes = previously diagnosed index cases; SI = simulation interval

^a Does not include reengagement of previously diagnosed persons to ART
^b Does not include reengagement of partners to ART
^c Compared to the base scenario

Table 3.
HIV Partner Services Expansion: Impacts of Joint Cascade Step Improvements (Theoretical Maxima) on HIV Epidemiological Outcomes Among Atlanta Gay, Bisexual, and Other Men who Have Sex with Men (GBMSM)

Scenarios	Incidence Rate at Year 10		Cum. Incidence Over 10 Yrs.		Number of Infections Averted Over 10 Years ^b		Percent Infections Averted Over 10 Years ^b		NNT	
	Median (95% SI)		Median (95% SI)		Median (95% SI)		Median (95% SI)		Median (95% SI)	
HIV Partner Services for Newly Diagnosed Index Cases only										
Base scenario	0.82 (0.75, 0.88)		8212 (7911, 8469)		-		-		-	
Counterfactual Scenarios										
All Indexes and All Partners Identified	0.82 (0.75, 0.90)		8153 (7905, 8441)		65 (-324, 436)		0.8 (-4.0, 5.1)		21 (-486, 398)	
+ All Partners HIV Screened	0.80 (0.73, 0.88)		8048 (7765, 8355)		156 (-217, 538)		1.9 (-2.7, 6.4)		24 (-517, 477)	
+ All Eligible Partners Provided PrEP	0.81 (0.74, 0.87)		8104 (7845, 8372)		104 (-254, 515)		1.3 (-3.1, 6.2)		24 (-575, 481)	
+ All Eligible Partners Linked to ART	0.82 (0.74, 0.89)		8138 (7860, 8451)		82 (-359, 553)		1.0 (-4.4, 6.5)		24 (-462, 873)	
+ All Eligible Partners Relinked to ART	0.75 (0.69, 0.82)		7669 (7384, 7931)		548 (171, 902)		6.7 (2.1, 10.7)		12 (7, 40)	
+ All Eligible Linked and Relinked to ART	0.76 (0.69, 0.83)		7658 (7400, 7951)		548 (98, 955)		6.7 (1.2, 11.3)		12 (6, 48)	
+ All Partner Services at Maxima ^a	0.73 (0.67, 0.79)		7458 (7211, 7683)		768 (385, 1089)		9.3 (4.8, 13.0)		9 (6, 18)	
HIV Partner Services for Newly & Previously Diagnosed Index Cases (No reengagement of previously diagnosed index cases to ART)										
Counterfactual Scenarios										
All Indexes and All Partners Identified	0.80 (0.73, 0.87)		7932 (7671, 8216)		285 (-137, 672)		3.5 (-1.7, 8.0)		229 (-1352, 1268)	
+ All Partners HIV Screened	0.77 (0.70, 0.84)		7702 (7451, 7992)		507 (147, 860)		6.2 (1.8, 10.2)		146 (82, 503)	
+ All Eligible Partners Provided PrEP	0.73 (0.66, 0.80)		7310 (7046, 7577)		894 (538, 1286)		10.9 (6.6, 15.4)		81 (55, 135)	
+ All Eligible Partners Linked to ART	0.79 (0.73, 0.87)		7918 (7645, 8182)		298 (-107, 678)		3.7 (-1.3, 8.0)		222 (-1233, 1462)	
+ All Eligible Partners Relinked to ART	0.65 (0.58, 0.71)		6646 (6439, 6905)		1579 (1202, 1885)		19.2 (14.8, 22.5)		35 (29, 47)	
+ All Eligible Linked and Relinked to ART	0.65 (0.59, 0.72)		6658 (6429, 6862)		1558 (1194, 1922)		19.0 (14.9, 23.0)		35 (28, 46)	
+ All Partner Services at Maxima	0.52 (0.46, 0.57)		5388 (5207, 5565)		2832 (2447, 3170)		34.5 (30.8, 37.4)		19 (17, 22)	
HIV Partner Services for Newly & Previously Diagnosed Index Cases (With reengagement of previously diagnosed index cases to ART)										
Counterfactual Scenarios										
All Indexes and All Partners Identified	0.30 (0.26, 0.35)		3596 (3443, 3793)		4618 (4291, 4887)		56.1 (53.5, 58.4)		5 (5, 6)	
+ All Partners HIV Screened	0.29 (0.25, 0.33)		3382 (3229, 3549)		4841 (4508, 5135)		58.8 (56.2, 61.0)		5 (5, 5)	
+ All Eligible Partners Provided PrEP	0.30 (0.25, 0.34)		3506 (3340, 3673)		4704 (4396, 5009)		57.3 (54.9, 59.7)		5 (5, 5)	
+ All Eligible Partners Linked to ART	0.30 (0.26, 0.36)		3588 (3416, 3754)		4631 (4275, 4934)		56.4 (53.4, 58.8)		5 (5, 6)	

Scenarios	Incidence Rate at Year 10		Cum. Incidence Over 10 Yrs.		Number of Infections Averted Over 10 Years ^b		Percent Infections Averted Over 10 Years ^b		NNT	
	Median (95% SI)		Median (95% SI)		Median (95% SI)		Median (95% SI)		Median (95% SI)	
+ All Eligible Partners Relinked to ART	0.29 (0.25, 0.35)		3458 (3293, 3640)		4744 (4402, 5078)		57.9 (55.1, 60.5)		5 (4, 5)	
+ All Eligible Linked and Relinked to ART	0.29 (0.25, 0.34)		3462 (3291, 3634)		4741 (4421, 5114)		57.8 (55.4, 60.5)		5 (4, 5)	
+ All Partner Services at Maxima	0.26 (0.22, 0.30)		3024 (2866, 3180)		5198 (4851, 5490)		63.1 (60.7, 65.2)		4 (4, 5)	
HIV Partner Services for Newly Diagnosed Index Cases with Inclusion of Wave-2 Partners (partners of partners to newly diagnosed index cases)										
Counterfactual Scenarios										
All Indexes and All Partners Identified	0.81 (0.74, 0.88)		8144 (7866, 8371)		78 (-274, 438)		0.9 (-3.5, 5.2)		24 (-272, 437)	
+ All Partners HIV Screened	0.80 (0.73, 0.87)		8017 (7732, 8332)		192 (-174, 569)		2.4 (-2.2, 6.8)		25 (-368, 495)	
+ All Eligible Partners Provided PrEP	0.81 (0.75, 0.89)		8048 (7767, 8320)		152 (-211, 533)		1.9 (-2.6, 6.3)		26 (-326, 341)	
+ All Eligible Partners Linked to ART	0.81 (0.74, 0.89)		8113 (7803, 8398)		102 (-305, 494)		1.2 (-3.8, 5.8)		23 (-500, 347)	
+ All Eligible Partners Relinked to ART	0.74 (0.67, 0.81)		7565 (7307, 7810)		650 (242, 1007)		7.8 (3.0, 12.0)		10 (6, 28)	
+ All Eligible Linked and Relinked to ART	0.74 (0.68, 0.81)		7552 (7288, 7786)		670 (255, 1031)		8.2 (3.2, 12.2)		10 (6, 25)	
+ All Partner Services at Maxima	0.71 (0.64, 0.77)		7282 (7051, 7512)		920 (539, 1287)		11.3 (6.8, 15.4)		7 (5, 12)	

Abbreviations: NIA = Number of infections averted over 10 years of intervention implementation; PIA = Percent of infections averted (compared to base scenario); NNT = Number needed to treat (i.e., number of indexes needed to be found/take part in partner services to avert 1 new HIV infection); ART = anti-retroviral therapy; PrEP = pre-exposure prophylaxis for HIV; PD-indexes = previously diagnosed index cases; SI = simulation interval.

^a All HIV partner service cascade steps set at maximal levels i.e., all eligible indexes and partners identified, all eligible partners screened, provided PrEP, linked/relinked to ART

^b Compared to the base scenario of the HIV Partner Services for Newly Diagnosed Cases only scenario