Cost-Effectiveness of a Statewide Pre-Exposure Prophylaxis Program for Gay, Bisexual, and Other Men Who Have Sex with Men

WILLIAM C. GOEDEL, BA; PHILIP A. CHAN, MD, MS; MAXIMILIAN R.F. KING, ScM; MATTIA C.F. PROSPERI, PhD; BRANDON D.L. MARSHALL, PhD; OMAR GALÁRRAGA, PhD

ABSTRACT

Pre-exposure prophylaxis (PrEP) is an effective tool for preventing HIV infection among men who have sex with men (MSM), but its cost-effectiveness has varied across settings. Using an agent-based model, we projected the cost-effectiveness of a statewide PrEP program for MSM in Rhode Island over the next decade. In the absence of PrEP, the model predicted an average of 830 new HIV infections over ten years. Scaling up the existing PrEP program to cover 15% of MSM with ten or more partners each year could reduce the number of new HIV infections by 33.1% at a cost of $184,234 per quality-adjusted life-year (QALY) gained. Expanded PrEP use among MSM at high risk for HIV infection has the potential to prevent a large number of new HIV infections but the high drug-related costs may limit the cost-effectiveness of this intervention.

KEYWORDS: HIV pre-exposure prophylaxis, agent-based modeling, cost-effectiveness, men who have sex with men

BACKGROUND

Similar to national trends,[1] men who have sex with men (MSM) represent the majority of people newly diagnosed and living with HIV infection in Rhode Island.[2] Once-daily pre-exposure prophylaxis (PrEP) represents an effective prevention tool that has the potential to decrease the number of new HIV infections occurring among MSM.[3]

Recent mathematical models have demonstrated that the expansion of PrEP use among MSM may have benefits at the population level in terms of reducing HIV incidence.[3-5] However, many studies have produced mixed results in terms of the cost-effectiveness of scaling up this intervention.[5-10] A recent analysis found that PrEP initiation among 20% of MSM in the United States would result in a 13% reduction in new HIV infections over 20 years but would not be considered cost-effective unless those most vulnerable to HIV infection were prioritized for PrEP initiation.[10]

As many jurisdictions make important decisions about supporting scale-up of PrEP use among MSM, the clinical and economic benefits in local settings must be understood. To date, few studies have expanded the cost-effectiveness of real-world PrEP implementation in specific settings with models parameterized to represent local epidemiologic and behavioral contexts.[8,9] In the current study, we simulated HIV transmission using an agent-based model representing all MSM in Rhode Island and considered the cost-effectiveness of various PrEP implementation scenarios.

METHODS

All model parameters and processes have been described previously.[11] In brief, the agent-based model simulated HIV transmission from 2013 to 2022 among a population of individuals (referred to as agents) representing all MSM in Rhode Island (n = 25,000). The agents in the model were assigned specific demographic, behavioral, and clinical characteristics with distributions informed by data on MSM in Rhode Island, with estimates from the literature used as needed (**Table 1**).

The model progressed in a series of discrete time-steps, each representing one calendar month. During each time-step, agents were able to form and dissolve sexual partnerships. In the context of serodiscordant partnerships, agents could

Table 1. Key parameter values for cost-effectiveness of PrEP implementation among MSM in RI

Parameter	Value
Pre-exposure prophylaxis (PrEP) use	
Retention in clinical care	
6 months post-initiation	54.0%
Monthly probability of discontinuation (7+ months post-initiation)	15.0%
Pill adherence	
4 to 7 doses per week	82.0%
2 to 3 doses per week	18.0%
Reduction in risk of HIV acquisition	
4 to 7 doses per week	96.0%
2 to 3 doses per week	76.0%
Costs (2015 U.S. dollars)	
Annual cost of PrEP, per patient	$10,664
Lifetime cost of HIV treatment, per patient	$337,036
Utility	
Quality-adjusted life-year gained per averted infection	5.83

acquire HIV infection by engaging in condomless anal intercourse. Following infection, an agent could be tested and diagnosed, initiate antiretroviral treatment, or achieve viral suppression. Agents without HIV infection were eligible to initiate PrEP use based on the specific allocation scenario. Those who initiated PrEP could achieve an optimal level of adherence and discontinue PrEP use at any time (**Table 1**).

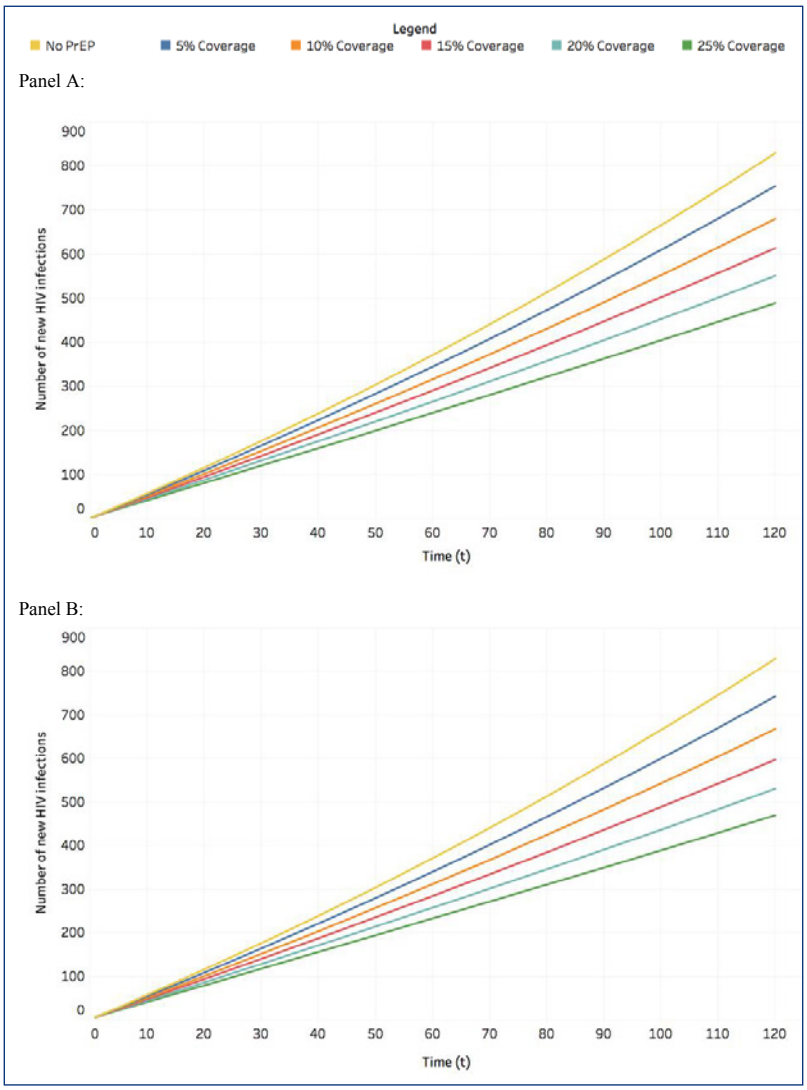
Model Scenarios

The model predicted the total number of new HIV infections over ten years under three PrEP allocation scenarios with varying levels of intervention coverage (5% to 25%, in 5% increments). The first set of scenario allocated PrEP to individuals similar to those currently receiving PrEP from the Rhode Island STD Clinic,[11] while the two other sets of scenarios allocated PrEP to MSM with at least five or ten sexual partners each year, respectively. Each scenario is simulated for 1,000 iterations. Each scenario summarized as the mean number of HIV infections averted relative to a 'status quo' scenario where PrEP implementation does not occur.

Cost and Utility Assumptions

The annual operating cost of providing PrEP to one patient was estimated using a health system perspective (**Table 1**). Costs were derived from an analysis of the PrEP program at the Rhode Island STD Clinic.[12] For each scenario, we calculated the cost per quality-adjusted life-year (QALY) gained relative to the 'status quo' scenario. Based on current guidelines, a scenario was considered cost-effective if this value was under a threshold under $100,000 QALY gained. Because drug-related costs represent the primary driver of program costs, we conducted sensitivity analyses where these costs were reduced (10% to 90%, in 10% increments).

Figure 1. Cumulative number of HIV infections among MSM in Rhode Island from 2013 to 2022 with varying PrEP coverage (a) with scale-up among the current patient population of the RI STD Clinic; (b) targeted scale-up to individuals with greater than 5 partners per year; and (c) targeted scale-up to individuals with greater than 10 partners per year, relative to a scenario where PrEP is not available.



RESULTS

In the absence of PrEP use, the model estimated an average of 830 new HIV infections over ten years, corresponding to an incidence rate of 3.5 infections per 1,000 person-years. With all strategies, increasing PrEP use resulted in proportionate reductions in HIV incidence (**Figure 1**).

If the current patient population served by the PrEP program were to be scaled up to cover 15% of MSM for ten years, the cumulative number of new HIV infections could be reduced by 26.1%. This scenario generated an increment $305 billion in healthcare-related costs and $73 billion in savings on HIV care, corresponding to $260,050 per QALY gained. Although increasing coverage to 25% would reduce the number of new HIV infections by 41.1%, the total cost and incremental cost-effectiveness increased because of the diminished benefits of additional PrEP use (**Table 2**).

Should 15% of MSM with five or more sexual partners each year use PrEP over the next ten years, the cumulative number of new HIV infections could be reduced by 28.0%. This allocation strategy improved cost-effectiveness, where the cost per QALY gained was reduced to $235,358. An allocation strategy that initiated 15% of MSM with ten or more sexual partners each year to use PrEP over a decade could reduce the number of new HIV infections by 33.1% and further reduce the cost per QALY gained to $184,234. Despite

Table 2. Incremental cost effectiveness ratios of PrEP scale-up among MSM in RI from 2013 to 2022, with varying coverage (a) with scale-up among the current patient population of the RI STD Clinic; (b) targeted scale-up to individuals with greater than 5 partners per year; and (c) targeted scale-up to individuals with greater than 10 partners per year, relative to a scenario where PrEP is not available.

	5%	10%	15%	20%	25%
Current Patients	$227,856	$230,315	$241,631	$252,067	$259,607
>5 partners	$190,177	$208,861	$220,966	$231,417	$242,783
>10 partners	$160,625	$178,251	$182,189	$182,189	$181,545

Legend	
	Cost-Saving
	< $20,000/QALY
	< $100,000/QALY
	> $100,000/QALY

these reductions in incremental costs, neither of these strategies were considered cost-effective based on a standard threshold of $100,000.

Drug-related costs have considerable effect on the cost-effectiveness of PrEP implementation. Were the annual drug-related costs to be reduced by 40%, for example, the cost per QALY gained when 15% of MSM with five or more partners use PrEP is reduced to $118,085. Under a standard threshold of $100,000, a scenario where 15% of MSM with ten or more partners used PrEP would be considered cost-effective with this reduction in drug-related costs ($87,416 per QALY gained).

DISCUSSION

This analysis demonstrates that the use of PrEP in MSM could have a substantial impact on the HIV epidemic in Rhode Island. If the current PrEP program at the Rhode Island STD Clinic were to be scaled up to cover 15% of MSM in the state over ten years, one-quarter of new infections could be prevented. However, PrEP is a costly intervention, largely due to the high costs of the drugs used in PrEP. If the annual cost of PrEP decreased by at least 40%, PrEP could be considered broadly cost-effective in this setting.

Several other studies have also found that PrEP implementation among MSM in the United States may be cost-effective when targeted to individuals at highest risk for HIV infection, and that the cost-effectiveness of PrEP use is dependent on the associated drug costs. As such, future research should investigate strategies to improve the efficiency of PrEP use in averting HIV infections or reducing the costs associated with PrEP use in this setting. Although patients at the Rhode Island STD Clinic are prescribed PrEP in line with current guidelines,[13] individuals may use PrEP even if they report fewer risk behaviors, decreasing its impact on HIV transmission while increasing costs. PrEP may be made more efficient in averting HIV infections if its uptake is targeted to those located centrally in sexual networks at high-risk for HIV infection.[14]

These analyses are not without limitation. The model does not account for the possibility that PrEP use may facilitate the emergence of drug resistance among those who initiate PrEP during acute HIV infection or those who acquire HIV infection with sub-therapeutic drug concentrations.[15,16] A previous study found that the emergence of drug resistance due to the PrEP largely does not affect cost-effectiveness.[10] In addition, the model does not account for co-circulating STIs. As such, an individual's probability of HIV transmission or acquisition may be underestimated, as these probabilities may be higher for individuals with a bacterial STI.[17] In addition, previous modeling studies have suggested that the regular screening of individuals using PrEP for STIs has benefits at the population level.[18] As such, we may underestimate the true health care costs saved due to PrEP use and the associated testing and treatment of other STIs.

CONCLUSION

We found that PrEP use among MSM in Rhode Island has the potential to prevent a considerable number of new HIV infections over a decade. However, expanded PrEP use is expensive. PrEP use among MSM at high risk of HIV acquisition provides substantial benefits at a lower cost, although its budgetary impact is still sizable. The high drug-related costs of PrEP are a significant barrier to cost-effective scale-up of PrEP implementation in this context. Drug costs must be reduced for PrEP to become an affordable HIV prevention option.

Acknowledgments

We thank Jesse L. Yedinak, MPA, for her administrative assistance. This work was supported by the National Institute of Mental Health (R21MH109360). Mr. Goedel is further supported by the National Institute of Mental Health (R25MH083620). The views expressed herein are those of the authors and do not necessarily reflect the views of the National Institutes of Health.

References

1. Grey JA, Bernstein KT, Sullivan PS, Purcell DW, Chesson HW, Gift TL, et al. Estimating the population sizes of men who have sex with men in US states and counties using data from the American Community Survey. JMIR Public Health Surveill. 2016;2(1):e14.
2. Rhode Island Department of Health. 2016 Rhode Island HIV Epidemiologic Profile with Surrogate Data. Providence, Rhode Island: Division of Preparedness, Response, Infectious Disease, and Emergency Medical Services; 2017.
3. Jenness SM, Goodreau SM, Rosenberg E, Beylerian EN, Hoover KW, Smith DK, et al. Impact of the Centers for Disease Control's HIV preexposure prophylaxis guidelines for men who have sex with men in the United States. J Infect Dis. 2016;214(12):1800-7.
4. LeVasseur MT, Goldstein ND, Tabb LP, Olivieri-Mui BL, Welles SL. The effect of PrEP on HIV incidence among men who have sex with men in the context of condom use, treatment as prevention, and seroadaptive practices. J Acquir Immune Defic Syndr. 2018;77(1):31-40.

5. Desai K, Sansom SL, Ackers ML, Stewart SR, Hall HI, Hu DJ, et al. Modeling the impact of HIV chemoprophylaxis strategies among men who have sex with men in the United States: HIV infections prevented and cost-effectiveness. AIDS. 2008;22(14):1829-39.
6. Koppenhaver RT, Sorensen SW, Farnham PG, Sansom SL. The cost-effectiveness of pre-exposure prophylaxis in men who have sex with men in the United States: An epidemic model. J Acquir Immune Defic Syndr. 2011;58(2):e51-e2.
7. Adamson BJ, Carlson JJ, Kublin JG, Garrison LP. The potential cost-effectiveness of pre-exposure prophylaxis combined with HIV vaccines in the United States. Vaccines. 2017;5(2):13.
8. Drabo EF, Hay JW, Vardavas R, Wagner ZR, Sood N. A cost-effectiveness analysis of preexposure prophylaxis for the prevention of HIV among los angeles county men who have sex with men. Clin Infect Dis. 2016;63(11):1495-504.
9. Kessler J, Myers JE, Nucifora KA, Mensah N, Toohey C, Khademi A, et al. Evaluating the impact of prioritization of antiretroviral pre-exposure prophylaxis (PrEP) in New York City. AIDS. 2014;28(18):2683-91.
10. Juusola JL, Brandeau ML, Owens DK, Bendavid E. The cost-effectiveness of preexposure prophylaxis for HIV prevention in the United States in men who have sex with men. Ann Intern Med. 2012;156(8):541-50.
11. Gantenberg JR, King MRF, Montgomery MC, Galarraga O, Prosperi MCF, Chan PA, et al. Improving the impact of HIV pre-exposure prophylaxis implementation in small urban centers among men who have sex with men: An agent-based modelling study. PLoS One. 2018;13(7):e0199915.
12. Younus A. Cost analysis of a pre-exposure prophylaxis (PrEP) program for HIV prevention in Rhode Island: A micro-costing approach. Providence, Rhode Island: Brown University; 2017.
13. United States Public Health Service. Preexposure Prophylaxis for the Prevention of HIV Infection in the United States: A Clinical Practice Guideline. Atlanta, Georgia: Centers for Disease Control and Prevention; 2014.
14. Lee SS, Tam DK, Tan Y, Mak WL, Wong KH, Chen JH, et al. An exploratory study on the social and genotypic clustering of HIV infection in men having sex with men. AIDS. 2009;23(13):1755-64.
15. Liegler T, Abdel-Mohsen M, Bentley LG, Atchison R, Schmidt T, Javier J, et al. HIV-1 drug resistance in the iPrEx preexposure prophylaxis trial. J Infect Dis. 2014;210(8):1217-27.
16. Parikh UM, Mellors JW. Should we fear resistance from tenofovir/emtricitabine PrEP? Curr Opin HIV AIDS. 2016;11(1):49-55.
17. Ward H, Rönn M. The contribution of STIs to the sexual transmission of HIV. Curr Opin HIV AIDS. 2010;5(4):305-10.
18. Jenness SM, Weiss KM, Goodreau SM, Gift T, Chesson H, Hoover KW, et al. Incidence of Gonorrhea and Chlamydia following human immunodeficiency virus preexposure prophylaxis among men who have sex with men: a modeling study. Clin Infect Dis. 2017;65(5):712-8.

Authors

William C. Goedel, BA, Department of Epidemiology, School of Public Health, Brown University, Providence, RI.

Philip A. Chan, MD, MS, Department of Medicine, Warren Alpert Medical School, Brown University, Providence, RI.

Maximilian R.F. King, ScM, Department of Epidemiology, School of Public Health, Brown University, Providence, RI.

Mattia C.F. Prosperi, PhD, Department of Epidemiology, College of Public Health and Health Professions, University of Florida, Gainesville, Fl.

Brandon D.L. Marshall, PhD, Department of Epidemiology, School of Public Health, Brown University, Providence, RI.

Omar Galárraga, PhD, Department of Health Services, Policy, and Practice, School of Public Health, Brown University, Providence, RI.

Correspondence

Brandon D.L. Marshall, PhD
Brown University School of Public Health
Department of Epidemiology
121 South Main Street, Box G-S121-2
Providence, RI 02912