PROJECTING THE IMPACT OF IMPLEMENTING PRE-EXPOSURE PROPHYLAXIS FOR HIV AMONG MEN WHO HAVE SEX WITH MEN IN BALTIMORE CITY

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ABSTRACT

Men who have sex with men (MSM) experience over half of new HIV infections annually in Baltimore city. Oral pre-exposure prophylaxis (PrEP) and antiretroviral therapy (ART) are likely to play central roles in reducing the risk of HIV transmission. However, the likely combined impact of these interventions remains uncertain. We propose an individual-based simulation approach to project the population-level impact of implementing PrEP for high-risk MSM in Baltimore, with different levels of coverage and adherence. The primary outcome is the HIV incidence over five years. We project non-linear relationships between program coverage, individual-level adherence, and population-level impact. The impact of PrEP increases with time but is not sustained if PrEP provision ceases. Expansion of ART coverage can augment the impact of PrEP on HIV incidence over the next decade.

1   INTRODUCTION

While only accounting for an estimated 4% of the United States population, MSM experience 63% of all new infections in this country (78% of the infections among men). Strategies to end the HIV epidemic in the United States must therefore focus strongly on this population. Oral pre-exposure prophylaxis (PrEP) and antiretroviral therapy (ART) are both pharmacological interventions that – when taken consistently – reduce the risk of male-to-male sexual HIV transmission by 95% or more. However, both coverage (the number of eligible individuals offered treatment) and adherence (the number of those offered treatment who take it consistently) to PrEP and ART are suboptimal among young MSM. The Baltimore City HIV Planning Group and Commission has a Work Group dedicated to implementation of PrEP; however, this Work Group (and other decision-makers in the City) currently lack a framework for understanding the levels of PrEP and ART coverage and adherence among young MSM that would be required to end the HIV epidemic in this city.

Agent-based modeling is a powerful simulation approach that allows for construction of populations with individual-level characteristics that determine behavior. This approach has been successfully applied to project the impact of a number of key HIV control interventions, including combination prevention in South Africa, male circumcision, and individualized testing. To date, however, no published agent-based model to our knowledge has been used to estimate the combined impact of PrEP and ART on HIV incidence at the city level. Furthermore, no agent-based model has attempted to incorporate data on within-city geography to inform sexual transmission networks. Construction of an agent-based model of the MSM population of Baltimore City will provide a flexible framework through which data from multiple local sources (including epidemiological studies and surveillance data) can be integrated to provide a comprehensive picture of the HIV epidemic in this population, and to chart a path by which that epidemic can be ended using available and/or new resources.

2   METHOD

Our agent-based simulation model of the HIV epidemic among MSM in Baltimore City is structured as a collection of different modules that govern various aspects of population dynamics, disease transmission, progression and control. Each agent represents a single MSM in Baltimore City, characterized by his age, race, and location of residence. The model is evaluated in a series of one-week time steps. The natural history module characterizes the progression of HIV among infected individuals according to disease stage (acute, early, and late). Each stage is associated with a different per-act risk of HIV transmission, and progression from early to late disease can be prevented (and/or reversed) by provision of ART. The continuum of care module estimates individuals' probabilities of HIV testing, linkage to care, disengagement/re-engagement, and ART provision/viral suppression at each time step. The sexual network and transmission module creates and modifies the population's sexual networks (as a series of stable/long-term and casual/short-term partnerships) at each step, modeling HIV transmission as a per-act probability among serodiscordant partnerships according to type of sex act, condom use, HIV stage of the infected partner, and ART/PrEP use. Sexual partnerships are modeled as assortative according to age, race, and location of residence (within neighborhood of residence, and within contiguous neighboring locations that are similar according to race and socioeconomic status). Finally, the demographic module accounts for aging and natural birth/death processes.

Model outputs are calibrated to data from the Maryland department of health and mental hygiene (DHMH) and National HIV Behavioral surveillance in Baltimore (BESURE) [1]. Our primary outcome is the projected reduction in HIV incidence over five years, comparing a number of PrEP scenarios (at different levels of coverage and adherence) to a baseline counterfactual in the absence of PrEP. We consider three scenarios for provision of PrEP. In each scenario, a proportion of eligible individuals reporting more than one sexual partner in the past year (corresponding to "coverage") will receive PrEP at the beginning of each year. Individual-level "adherence" to PrEP is modeled as the proportion of days on which an individual receiving PrEP is protected against HIV transmission. The first scenario assumes a fixed level of coverage through five years among the same individuals (i.e., no discontinuation). The second scenario assumes a fixed coverage with a 50% probability of discontinuation at the end of each year, such that individuals taking PrEP are replaced by other individuals on an annual basis. The third scenario assumes a linearly increasing coverage over time, as well as the 50% annual probability of discontinuation as in the second scenario. Coverage and adherence are varied from 0% to 100% in all scenarios.

3   RESULTS & CONCLUSION

Our results suggest a non-linear increase in the impact of PrEP as a function of program coverage and individual-level adherence. The overall impact increases with time, achieving 90% reduction incidence by the end of the fifth year under assumptions of very high coverage and adherence. Under the assumption that PrEP delivery ends at the end of year five, HIV incidence immediately returns to its baseline level in year six, with only minimal ongoing reductions (no greater than 20%, relative to baseline) in ensuing years if PrEP is not continued. Assumptions about discontinuation had no impact on projected results at any given level of adherence or coverage, but this may reflect an assumption that sexual behavior in one year has no correlation to such behavior in subsequent years. Delayed scale-up of PrEP substantially reduced its impact relative to immediate scale-up to a fixed level. Additional synergistic declines in incidence can be achieved by scaling up underlying ART coverage among the population with known HIV infection. Areas for future research include addition of various risk groups, heterogeneous mixing patterns, better characterization of sexual behavior over time, and further evaluation of PrEP provision in combination with increased levels of ART.

REFERENCE

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