**Epidemiological Impact of Expedited Partner Therapy for Men Who Have Sex With Men: A Modeling Study**

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*Supplementary Technical Appendix*

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# 1 INTRODUCTION

This supplementary technical appendix describes the mathematical model structure, parameterization, and statistical analysis of the accompanying paper in further detail.

## 1.1 Model Framework

The mathematical models for HIV transmission dynamics presented in this study are agent-based microsimulation models in which uniquely identifiable sexual partnership dyads were simulated and tracked over time. This partnership structure is represented using separable temporal exponential-family random graph models (STERGMs), described in Section 2. On top of this dynamic network simulation, the larger epidemic model represents demography (entries, exits, and aging), interhost epidemiology (disease transmission), intrahost epidemiology (disease progression), and clinical epidemiology (disease diagnosis and treatment). Individual attributes related to these processes are stored and updated in discrete time over the course of each epidemic simulation.

The modeling methods presented here depend upon and extend the *EpiModel* software to incorporate HIV-specific epidemiology. The HIV extensions for men who have sex with men (MSM) were originally developed by Goodreau et al. for use in prior modeling studies of MSM in the United States and South America,1–3 and subsequently used for models of HIV preexposure prophylaxis (PrEP) among US MSM.4,5

The model algorithms and methods presented here generalize these prior MSM HIV transmission models to investigate emerging and established HIV and STI prevention methods such as regular screening for HIV and STIs as part of a collaborative modeling effort (the Coalition for Applied Modeling for Prevention) between Emory University, the University of Washington, the Centers for Disease Control and Prevention, and local health public departments [http://emorycamp.org/].

## 1.2 Model Software

The models in this study were programmed in the R and C++ software languages using the *EpiModel* [http://epimodel.org/] software platform for epidemic modeling. *EpiModel* was developed by the authors for simulating complex network-based mathematical models of infectious diseases, with a primary focus on HIV and other sexually transmitted infections (STIs). *EpiModel* depends on *Statnet* [http://statnet.org/], a suite of software in R for the representation, visualization, and statistical analysis of complex network data.6

*EpiModel* allows for a modular expansion of its built-in modeling tools to address novel research questions. For this current research study, we have developed extension modules into an add-on software package to *EpiModel* called *EpiModelHIV*. This open-source software is available for download, along with the scripts used in the execution of these models. The tools and scripts to run these models are contained in two GitHub software repositories:

* [http://github.com/EpiModel/EpiModelHIV] contains the general extension software package. Installing this using the instructions listed at the repository homepage will also load in *EpiModel* and the other dependencies. We use a branching software architecture such that the version of the software associated with this research project is *new\_ept.*
* [http://github.com/EpiModel/EPT] contains the scripts to execute the mathematical models and to run the statistical analyses provided in the manuscript.

# 2 DYNAMIC NETWORKS OF SEXUAL PARTNERSHIPS

We modeled networks of three interacting types of sexual relations: main partnerships, casual (but persistent) partnerships, and one-time anal intercourse (AI) contacts. We first describe the methods conceptually, including the parameters used to guide the model and their derivation (Section 2.1), and then present the formal statistical modeling methods (Section 2.2). Consistent with our parameter derivations, all relationships are defined as those in which AI is expected to occur at least once.

## 2.1 Conceptual Representation of Sexual Networks

Our modeling methods aim to preserve certain features of the cross-sectional and dynamic network structure as reported in behavioral studies, while also allowing for mean relational durations to be targeted to those reported for different groups and relational types. These methods do so all within the context of changing population size (due to births, deaths, arrivals, and departures from the population) and changing composition by attributes such as age and disease status.

The network features that we aim to preserve are as follows, with the parameters for each described in turn:

* The proportion of men in any given combination of main and casual partnerships (for example, in 1 main and 0 casual partnerships) at any time point.
* The expected number of one-time contacts per time step had by men in each main-casual combination.
* Variation across men in the numbers of one-time contacts.
* Age mixing within each of the different relational types.
* Prohibitions against partnering for two men who are both exclusively insertive or both exclusively receptive.

*2.1.1 Number of Ongoing Main and Casual Partnerships*

Ongoing partnerships (whether main or casual) were defined from the combined dyadic dataset as those in which sex had already occurred more than once, and in which the respondent anticipated having sex again. Within this set, partnerships were defined as main if the respondent indicated that it was someone they “felt committed to above all others” or that they considered the person their “primary sex partner”; if neither of these conditions held, the partner was defined as casual.This yielded the following proportions of men with a given number of main and casual relationships at a point in time (i.e. the expected *momentary degree distribution*):

|  |  |  |  |
| --- | --- | --- | --- |
|  | *0 Casual* | *1 Casual* | *2 Casual* |
| *0 Main* | 47.1% | 16.7% | 7.4% |
| *1 Main* | 22.0% | 4.7% | 2.1% |

*2.1.2 Expected Number of One-Time AI Contacts, by Main/Casual Degree*

Respondentsin the combined dyadic dataset were asked whether they had had sex with each partner once or more than once; the former response led to the contact being defined as one-time. These contacts cannot be analyzed in terms of momentary degree distributions, since, by definition, none are ongoing at the point of interview. Instead, we turn the observed frequencies into expected rates of one-time contacts per time step for men under different conditions. One of the sources of heterogeneity in men’s propensity for one-time AI contacts is their current relationship status. The expected numbers are given by:

|  |  |  |  |
| --- | --- | --- | --- |
|  | *0 Casual* | *1 Casual* | *2 Casual* |
| *0 Main* | 0.065 | 0.087 | 0.086 |
| *1 Main* | 0.056 | 0.055 | 0.055 |

*2.1.3 Heterogeneity in the One-Time Contact Rate*

In addition to differences by relational status, men also have underlying fixed heterogeneities in their propensity to engage in one-time AI. The distribution of one-time contacts was divided into quintiles, within which the expected values of one-time AI per time step are:

|  |  |
| --- | --- |
| **Quintile** | **Value** |
| Lowest quintile | 0.000 |
| Second quintile | 0.007 |
| Third quintile | 0.038 |
| Fourth quintile | 0.071 |
| Highest quintile | 0.221 |

Men are assigned a quintile upon entry into the population, which remains fixed. Any individual man’s propensity for AI is determined as a combination of their quintile and their current main/casual partnership counts. Our statistical methods (described below) translate both propensities into conditional log-odds, allowing for their combination. Note that the means of the columns in the quintile table equal the means of the values in Section 2.1.2 weighted by the proportions in Section 2.1.1. These reflect the overall expected value across all men for one-time AI acts per time step.

*2.1.4 Age Mixing*

Respondents also reported on the estimated age of each partner.We model age mixing within a given relational type using a single parameter for each, the expected mean difference in square root of the ages of men in a relationship, consistent with previous work.1,3,7 For instance, a relationship between a 23-year-old and a 28-year-old would represent $\left|\sqrt{23}-\sqrt{28}\right|$ = 0.496.

|  |  |
| --- | --- |
|  | **Value** |
| Main partnerships | 0.464 |
| Casual partnerships | 0.586 |
| One-time contacts | 0.544 |

*2.1.5 Mixing by Sexual Role*

We assign men a fixed sexual role preference (exclusively insertive, exclusively receptive, or versatile). The model then includes an absolute prohibition, such that two exclusively insertive men cannot partner, nor can two exclusively receptive men. Men’s roles at last sex for each of the last 5 (Involvement) or 10 (MAN Project) partners were aggregated; those who had engaged in one role across all those acts in those partnerships were deemed to be exclusively receptive or insertive, and those who had engaged in at least one act of each were deemed to be versatile. In the absence of longitudinal behavioral data, sexual role preference was assumed to be a fixed trait, rather than a time-varying one, although, for versatile men, the sexual role within each partnership at each simulated time step was stochastic.

|  |  |
| --- | --- |
|  | **Probability** |
| Exclusively insertive | 24.2% |
| Versatile | 43.7% |
| Exclusively receptive | 32.1% |

*2.1.6 Partnership Durations*

We model relational dissolution as a memoryless process with a single parameter per relational type. This implies an exponential distribution for relational durations within each category. As detailed in previous work,1 for memoryless processes, the expected age of an extant relationship at any moment in time matches the expected uncensored duration of relationships, given the balancing effects of right-censoring and length bias for this distribution. To derive our values, we take the median of the observed distribution and then calculate the mean for the exponential distribution with that median. Duration was calculated as the difference between first and last sex date for each dyad the ego reported sex with more than once in the interval. The resulting expected relational durations were:

|  |  |
| --- | --- |
|  | **Duration** |
| Main partnerships | 407 days |
| Casual partnerships | 166 days |

## 2.2 Statistical Representation of Sexual Networks

Exponential-family random graph models (ERGMs) and their dynamic extension, separable temporal ERGMs (STERGMs), provide a foundation for statistically principled simulation of local and global network structure given a set of target statistics from empirical data. Main and casual relationships were modeled using STERGMs,8 since they persist for multiple time steps. One-time contacts, on the other hand, were modeled using cross-sectional ERGMs.9 Formally, our statistical models for relational dynamics can be represented as five equations for the conditional log odds (logits) of relational formation and persistence at time *t* (for main and casual relationships) or for relational existence at time *t* (for one-time contacts):

$logit\left(P\left( Y\_{ij,t-1}=0, Y\_{ij,t}^{C}\right)\right) = θ\_{m}^{+}^{'}∂\left(g\_{m}^{+}\left(y\right)\right)$ Main partnership formation

$logit\left(P\left( Y\_{ij,t-1}=0, Y\_{ij,t}^{C}\right)\right) = θ\_{c}^{+}^{'}∂\left(g\_{c}^{+}\left(y\right)\right)$ Casual partnership formation

$logit\left(P\left( Y\_{ij,t-1}=1, Y\_{ij,t}^{C}\right)\right) = θ\_{m}^{-}^{'}∂\left(g\_{m}^{-}\left(y\right)\right)$ Main partnership persistence

$logit\left(P\left( Y\_{ij,t-1}=1, Y\_{ij,t}^{C}\right)\right) = θ\_{c}^{-}^{'}∂\left(g\_{c}^{-}\left(y\right)\right)$ Casual partnership persistence

$logit\left(P\left( Y\_{ij,t}^{C}\right)\right) = θ\_{o}^{'}∂\left(g\_{o}\left(y\right)\right)$ One-time contact existence

where:

* $Y\_{ij,t}$ = the relational status of persons *i* and *j* at time *t* (1 = in relationship/contact, 0 = not)
* $Y\_{ij,t}^{C}$ = the network complement of *i,j* at time *t*,i.e. all relations in the network other than *i,j*
* $g\left(y\right)$ = vector of network statistics in each model
* $θ$= vector of parameters in the formation model

For $g\left(y\right)$ and $θ$, the superscript distinguishes the formation model (+), persistence model (-) and existence models (neither). The subscript indicates the main (m), casual (c) and one-time (o) models.

The recursive dependence among the relationships renders the model impossible to evaluate using standard techniques; we use Markov chain Monte Carlo (MCMC) methods in order to obtain the maximum likelihood estimates for the$θ$ vectors given the $g\left(y\right)$vectors.

Specific model statistics are listed below. Together these sets allow us to retain all network features listed in Section 2.1. It is important to note that, although the statistics are expressed here in terms of number of relationships and are entered into the estimation model in this form, the simulation model is then parameterized using the resulting $θ$ coefficients. This means that, as population size and composition changes, it is not the absolute number of relationships of different kinds that will be preserved, but the relative numbers (e.g. the mean number of relationships per person). Similar conversions hold for the other statistics (e.g. the mean age difference per relationship is preserved, not the sum across all relationships).

Main partner formation model statistics: $g\_{m}^{+}\left(y\right)$ vector:

* $g\_{m1}^{+}\left(y\right)$ = number of main partnerships
* $g\_{m2}^{+}\left(y\right)$ = number of men with 2+ main partners
* $g\_{m3}^{+}\left(y\right)$ = number of main partnerships for men with 1 casual partner
* $g\_{m4}^{+}\left(y\right)$ = number of main partnerships for men with 2 casual partners
* $g\_{m5}^{+}\left(y\right)$ = sum of the absolute difference in the square root of partners’ ages across main partnerships
* $g\_{m6}^{+}\left(y\right)$ = number of main partnerships between men who were both exclusively insertive
* $g\_{m7}^{+}\left(y\right)$ = number of main partnerships between men who were both exclusively receptive

There are structural zeroes as coefficient constraints for the terms $g\_{m2}^{+}\left(y\right)$, $g\_{m6}^{+}\left(y\right)$, $g\_{m7}^{+}\left(y\right)$. This means that the logit values for their coefficients are set to negative infinity to ensure that no partnerships of these types occur.

Main partner persistence model terms: $g\_{m}^{-}\left(y\right)$ vector:

* $g\_{m1}^{-}\left(y\right)$ = number of main partnerships

Casual partner formation model terms: $g\_{c}^{+}\left(y\right)$ vector:

* $g\_{c1}^{+}\left(y\right)$ = number of casual partnerships
* $g\_{c2}^{+}\left(y\right)$ = number of casual partnerships for men with 1 main partner
* $g\_{c3}^{+}\left(y\right)$ = number of men with 2 casual partners
* $g\_{c4}^{+}\left(y\right)$ = number of men with 3+ casual partners
* $g\_{c5}^{+}\left(y\right)$ = sum of the absolute difference in the square root of partners’ ages across casual partnerships
* $g\_{m6}^{+}\left(y\right)$ = number of casual partnerships between men who were both exclusively insertive
* $g\_{m7}^{+}\left(y\right)$ = number of casual partnerships between men who were both exclusively receptive

There are structural zeroes as coefficient constraints for the terms $g\_{m4}^{+}\left(y\right)$, $g\_{m6}^{+}\left(y\right)$, $g\_{m7}^{+}\left(y\right)$. This means that the logit values for their coefficients are set to negative infinity to ensure that no partnerships of these types occur.

Casual partner persistence model terms:$ g\_{c}^{-}\left(y\right)$ vector:

* $g\_{c1}^{-}\left(y\right)$ = number of casual partnerships

One-time contact existence model terms:$ g\_{o}\left(y\right)$ vector:

* $g\_{o1}\left(y\right)$ = number of one-time contacts
* $g\_{o2}\left(y\right)$ = total # of one-time contacts for men with 0 main and 1 casual partnership
* $g\_{o3}\left(y\right)$ = total # of one-time contacts for men with 0 main and 2 casual partnerships
* $g\_{o4}\left(y\right)$ = total # of one-time contacts for men with 1 main and 0 casual partnerships
* $g\_{o5}\left(y\right)$ = total # of one-time contacts for men with 1 main and 1 casual partnership
* $g\_{o6}\left(y\right)$ = total # of one-time contacts for men with 1 main and 2 casual partnerships
* $g\_{o7}\left(y\right)$ = total # of one-time contacts for men in risk quintile 1
* $g\_{o8}\left(y\right)$ = total # of one-time contacts for men in risk quintile 2
* $g\_{o9}\left(y\right)$ = total # of one-time contacts for men in risk quintile 4
* $g\_{o10}\left(y\right)$ = total # of one-time contacts for men in risk quintile 5
* $g\_{o11}\left(y\right)$= sum of the absolute difference in the square root of partners’ ages across one-time contacts
* $g\_{m12}^{+}\left(y\right)$ = number of one-time contacts between men who were both exclusively insertive
* $g\_{m13}^{+}\left(y\right)$ = number of one-time contacts between men who were both exclusively receptive

There are structural zeroes as coefficient constraints for the terms $g\_{m12}^{+}\left(y\right)$, $g\_{m13}^{+}\left(y\right)$. This means that the logit values for their coefficients are set to negative infinity to ensure that no partnerships of these types occur.

Our method of converting the statistics laid out in Section 2.1 into our fully specified network models consists of the following steps:

1. Construct a cross-sectional network of 10,000 men with no relationships.
2. Assign men sexual roles based on frequencies listed in Section 2.1.5, as well as one-time risk quintiles (20% of the men per quintile).
3. Calculate the target statistics (i.e., the expected count of each statistic at any given moment in time) associated with the terms in the formation model (for the main and casual partnerships) and in the existence model (for one-time contacts).
4. Assign each node a place-holder main and casual degree (number of on-going partnerships) that is consistent with degree matrices, and store these numbers as a nodal attribute. (Note: this does not actually require individuals to be paired up into the partnerships represented by those degrees).
5. For the main and casual networks, use the mean relational durations to calculate the parameters of the persistence model, using closed-form solutions, given that the models are dyadic-independent (each relationship’s persistence probability is independent of all others).
6. For the main and casual networks, estimate the coefficients for the formation model that represent the maximum likelihood estimates for the expected cross-sectional network structure.
7. For the one-off network, estimate the coefficients for the existence model that represent the maximum likelihood estimates for the expected cross-sectional network structure.

Steps 5–7 occur within the *Statnet* software and use the ERGM and STERGM methods therein. They are made most efficient by the use of an approximation in Step 6.10 During the subsequent model simulation, we use the method of Krivitsky et al.11 to adjust the coefficient for the first term in each model at each time step, in order to preserve the same expected mean degree (relationships per person) over time in the face of changing network size and nodal composition. At all stages of the project, simulated partnership networks were checked to ensure that they indeed retained the expected cross-sectional structure and relational durations throughout the simulations.

# 3 BEHAVIOR WITHIN SEXUAL PARTNERSHIPS

We model four phenomena consecutively within relationships at each time step: HIV+ status disclosure, number of anal sex acts, condom use per sex act, and sexual role per sex act.

## 3.1 Disclosure

We model the process by which someone who knows he is HIV-positive discloses this fact to partners of all types. Disclosure affects subsequent decision-making around condom use. We do not explicitly model other forms of serostatus discussion, since our source data do not include these; our behavioral estimates in the absence of HIV+ disclosure marginalize over those cases in which men disclose as concordant negative or do not discuss at all. Disclosure may occur at the point of a relation commencing (if HIV+ status is already known) or it may occur at the point of diagnosis, in the case of on-going relationships. In the former case, disclosure of HIV+ status was determined from the combined dyadic dataset using the HIV status of the respondent and their response to the question, “Did you and this partner share both of your HIV statuses before you first had sex?” In the latter case, we did not have data and assumed it to be universal.

|  |  |
| --- | --- |
| Probability of Disclosure of HIV+ Status | Probability |
|  to new main partner at outset of relationship | 78.7% |
|  to new casual partner at outset of relationship | 67.8% |
|  to one-time contact | 56.8% |
|  to ongoing partner if diagnosis occurs during relationship | 100% |

## 3.2 Number of AI Acts

The number of anal sex acts per week for each ongoing relationship is determined from a Poisson draw, with mean specific to the relational type. For one-time contacts, the number is set deterministically to 1 for the time step in which it occurs.

|  |  |
| --- | --- |
| **AI Acts/Week/Partnership** | **Frequency** |
| Main partnerships | 1.54 |
| Casual partnerships | 0.96 |

These rates were calculated based on the two Atlanta studies, derived from questions asking about the number of coital acts per partnership during the recall periods.10,11 These were then rescaled from the length of the recall period into the weekly rates listed in the table above.

## 3.3 Condom Use

We conducted logistic regressions to identify the significant predictors of condom use within HIV-discordant relationships (whether diagnosed or not) in our data. Respondents were asked if they had had unprotected anal sex with each partner during the recall periods.12,13 Predictors included the type of relationship, the HIV diagnosis status of the HIV+ partner (i.e. whether or not he himself knew that he was HIV+), and the disclosure status of the HIV+ partner (whether he had told his partner he was HIV+). Predictors that dropped out of the model included sexual position and perceived monogamy of the partnership.

Base model coefficients for the nine race/partnership types were defined as *logit*(P(condom use | anal intercourse):

|  |  |
| --- | --- |
|  | **Coefficient** |
| Main partnership | -1.325 |
| Casual partnership | -1.046 |
| One-time contact | -1.008 |

Note that for these, the reference category is the case in which the HIV+ man is undiagnosed, hence the relatively low values of condom use. Modifiers for these logit coefficients are:

|  |  |
| --- | --- |
| **Condition** | **Coefficient** |
| HIV+ diagnosis | 0.670 |
| HIV+ status disclosure | 0.850 |

Together, these values, in combination with the frequencies with which AI occurs in all types of situations, imply an overall rate of condom use of approximately 50% across all acts. The rates of condom use were assumed to be stable over the course of a given partnership, but condom usage was stochastic at each time step within that partnership. Differential condom usage rates by partnership type may capture effects of lower condom use that may occur in longer-term partnerships, but subsequent models will extend this model framework to incorporate network-related data to capture temporal trends in condom usage within each type of partnership.

## 3.4 Sexual Role

Men are assigned an individual sexual role preference (exclusively insertive, exclusively receptive, or versatile) as described in Section 2.1.5. Relationships between two exclusively insertive or two exclusively receptive men are prohibited via the ERGM and STERGM models. Versatile men are further assigned a preference for insertive behavior drawn from a uniform distribution between 0 and 1. When two versatile men are determined to have an AI act, their sexual positions must be determined (all other combinations have only one feasible combination). One option is for men to engage in intra-event versatility (IEV; i.e. both engage in insertive and receptive AI during the act). The probability of this is 49% and is derived from the partner-specific role data described in Section 2.1.5. If IEV does not occur, then each man’s probability of being the insertive partner equals his insertivity quotient divided by the sum of the two men’s insertivity quotients.

# 4 DEMOGRAPHY

In this model, there are three demographic processes: entries, exits, and aging. Entries and exits are conceptualized as flows to and from the sexually active population of interest: MSM aged 18 to 40 years old. Entry into this population represents the time at which persons become at risk of infection via male-to-male sexual intercourse, and we model these flows as starting at an age after birth (age 18) and ending at an age potentially before death (age 40).

## 4.1 Entry at Sexual Onset

All persons enter the network at age 18, which was the lower age boundary of our two main source studies. The number of new entries at each time step is based on a fixed rate (3 per 10,000 persons per weekly time step) that keeps the overall network size in a stable state over the time series of the simulations. The model parameter governing this rate was calibrated iteratively in order to generate simulations with a population size at equilibrium, given the inherent variability in population flows related to background mortality, sexual maturation (i.e., reaching the upper age limit of 40), and disease-induced mortality. At each time step, the exact number of men entering the population was simulated by drawing from a Poisson distribution with the rate parameter.

## 4.2 Initialization of Attributes

Persons entering the population were assigned attributes, some of which remained fixed by definition (e.g., race), others fixed by assumption (e.g., insertive versus receptive sexual role), and yet others allowed to vary over time (e.g., age and disease status). Here we describe three attributes in the first category:

* For **race/ethnicity**, this model was based on a population composition that was 50% black MSM and 50% white MSM. As noted, we did not explicitly model race within this study, and set all race-specific parameters to averages across stratified estimates. Subsequent models will extend this model framework to explore racial disparities related to PrEP uptake among MSM. This 1:1 ratio comes close to that for the Atlanta metropolitan area and provides analytical clarity.
* **Circumcision** status was randomly assigned to incoming men. Based on empirical data from Atlanta MSM,12 89.6% of men were circumcised before sexual onset. Circumcision was associated with a 60% reduction in the per-act probability of infection for HIV- males for insertive anal intercourse only (i.e., circumcision did not lower the *transmission* probability if the HIV+ partner was insertive).2,14
* The **CCR5-Δ32 genetic allele** was modeled by assigning a mutation for zero, one, or two chromosomes. Compared to men without a CCR5 mutation, heterozygous men (those with one mutation) were 70% less likely to become infected and homozygous men (those with two mutations) were fully immune from infection.15,16 The population distribution of CCR5 was differential by race, with 0% of black men and 3.4% of white men expressing as homozygous, and 2.1% of black men and 17.6% of white men expressing as heterozygous.15 But because race was not explicitly represented in these models, we averaged each set of proportions: 1.7% homozygous and 9.9% heterozygous overall.

## 4.3 Exits from the Network

All persons exited the network by age 40, either from mortality or reaching the upper age bound of the MSM target population of interest. This upper limit of 40 was modeled deterministically (probability = 1), but other exits due to mortality were modeled stochastically. Mortality included both natural (non-HIV) and disease-induced mortality causes before age 40. Background mortality rates were based on US all-cause mortality rates specific to age and race from the National Vital Statistics life tables.17 The following table shows the probability of mortality per year by age and race.

|  |  |  |
| --- | --- | --- |
| **Age** | **White** | **Black** |
| 18–24 | 0.00103 | 0.00159 |
| 25–34 | 0.00133 | 0.00225 |
| 35–39 | 0.00214 | 0.00348 |

Natural mortality was applied to persons within the population at each time step stochastically by drawing from a binomial distribution for each eligible person with a probability parameter corresponding to that person’s risk of death tied to his age. Disease-related mortality, in contrast, was modeled based on clinical disease progression, as described in Section 5.

## 4.4 Aging

The aging process in the population was linear by time step for all active persons. The unit of time step in these simulations was one week, and therefore, persons were aged in weekly steps between the minimum and maximum ages allow (18 and 40 years old). Evolving age impacted background mortality, age-based mixing in forming new partnerships, and other behavioral features of the epidemic model described below. Persons who exited the network were no longer active and their attributes such as age were no longer updated.

# 5 HIV INTRAHOST EPIDEMIOLOGY

Intrahost epidemiology includes features related to the natural disease progression within HIV+ persons in the absence of clinical intervention. The main component of progression that was explicitly modeled for this study was HIV viral load. In contrast to other modeling studies that model both CD4 and viral load, our study used viral load progression to control both interhost epidemiology (HIV transmission rates) and disease progression eventually leading to mortality.

Following prior approaches,1,2 we modeled changes in HIV viral load to account for the heightened viremia during acute-stage infection, viral set point during the long chronic stage of infection, and subsequent rise of VL at clinical AIDS towards disease-related mortality. A starting viral load of 0 is assigned to all persons upon infection. From there, the natural viral load curve is fit with the following parameters. The HIV viral load has a crucial impact on the rates of HIV transmission within serodiscordant couples in the model, and this interaction is detailed in Section 7. The parameters governing these processes are provided in the table below.

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Reference** |
| Time to peak viremia in acute stage | 45 days | Little18 |
| Level of peak viremia | 6.886 log10 | Little18 |
| Time from peak viremia to viral set point | 45 days | Little,18 Leynaert19 |
| Level of viral set point | 4.5 log10 | Little18 |
| Duration of chronic stage infection (no ART) | 3550 days | Buchbinder20,Katz21 |
| Duration of AIDS stage | 728 days | Buchbinder20 |
| Peak viral load during AIDS (at death) | 7 log10 | Estimated from average duration of AIDS |

After infection, it takes 45 days to reach peak viremia, at a level of 6.886 log 10. From peak viremia, it takes another 45 days to reach viral set point, which is set at a level of 4.5 log 10. The total time of acute stage infection is therefore 3 months. The duration of chronic stage infection in the absence of clinical intervention is 3550 days, or 9.7 years. The total duration of pre-AIDS disease from infection is therefore approximately 10 years. At onset of AIDS, HIV viral load rises linearly from 4.5 log 10 to 7 log 10, at which point mortality is assumed to occur. The time spent in the AIDS stage is 728 days, or 2 years. This viral load trajectory is for ART-naïve persons only, and the influence of ART on disease progression is detailed in Section 6. These transitions are deterministic for all ART-naïve persons.

# 6 HIV CLINICAL EPIDEMIOLOGY

Clinical epidemiological processes refer to all steps along the HIV care continuum after initial infection: diagnosis, linkage to care, treatment initiation and adherence, and HIV viral load suppression. In this model, these clinical features have critical interactions with behavioral features detailed above, as well as impacts on the rates of HIV transmission, detailed below. The features of our model’s clinical processes generally follow the steps of the HIV care continuum, in which persons transition across states from infection to diagnosis to medical care linkage and ART initiation to HIV viral suppression.22

## 6.1 HIV Diagnostic Testing

Persons in our models were divided into non-testers (through age 40) and regular interval-based testers. Based on empirical data for Atlanta MSM,12 6.5% of MSM did not receive HIV testing before age 40. This was calculated based on a survey question about never testing prior to the study, which may overestimate the final proportion who would have never tested before age 40. A fixed individual attribute for HIV treatment trajectories that characterized progression through the care continuum was randomly assigned upon entry into the population, with this group of 6.5% of MSM not accessing HIV testing or other forms of post-diagnostic HIV medical services.

The remaining 93.5% who entered the HIV care continuum HIV tested at regular intervals, with the estimated mean time between tests for HIV-negative persons at 301 days for black MSM and 315 days for white MSM.12,23 This was calculated based on time since last test in the survey, with the assumption that testing was a memoryless process. In this paper, we averaged over the two intervals since we did not explicitly model racial differences in the care continuum. Diagnostic testing was simulated stochastically using draws from a binomial distribution with probability parameters equal to the reciprocal of this interval. This generated a population-level geometric distribution of times since last test.

We also modeled a 21-day window period after infection during which the tests of the truly HIV+ persons would show as negative to account for the lack of antibody response immediately after infection.24 HIV+ persons who tested after this window period would be correctly diagnosed with 100% test sensitivity. Individual-level attributes for diagnosis status and time since last HIV test were recorded for all MSM.

## 6.2 Antiretroviral Therapy (ART) Initiation

Consistent with previous models,1,2 we simulated the initiation of ART and subsequent clinical outcomes of full or partial HIV viral suppression based on men being in one of three clinical states: never tested, on treatment and partially virally suppressed, and on treatment with full viral suppression. There was insufficient empirical data to represent the patterns and rates at which individual men switch among these three states over the course of their infection, since the clinical ART landscape is constantly evolving. Therefore, we modeled men as being on one of the three fixed treatment trajectories as an individual-level attribute such that our model matched the population-level data on the prevalence of durable HIV viral suppression and treatment-naïve mortality.25,26

Following HIV diagnosis (for the 93.5% of men who ever HIV test before age 40), MSM initiated treatment at a rate of 0.1095 per week. This translates into an average interval between testing and treatment initiation of 9.13 weeks, consistent with empirical data.23 In the absence of quantitative data, we assumed no gap between treatment entry and ART initiation.

## 6.3 ART Adherence and Viral Suppression

MSM who initiated ART could cycle on and off treatment, where cycling off treatment resulted in an increase in the VL back up to the assumed set point of 4.5 log10. The slope of changes to VL were calculated such that it took a total of 3 months to transition between the set point and the on-treatment viral loads.27 Men on treatment could achieve partial or full suppression. Men who with partial suppression were assumed to have a log10 viral load of 3.5, compared to 1.5 among those who were fully suppressed.27 The latter corresponds to an absolute viral load below the standard levels of detection (VL = 50).28

The patterns of ART adherence leading to partial and full HIV viral suppression were estimated based on an analysis of HIV care patterns among MSM in the United States,25 which was required in order to obtain parameters that were specific to young MSM by race. Parameterizing our model used three types of inputs: (1) the proportion of those diagnosed who are on ART; (2) the proportion of those diagnosed who are virally suppressed; (3) the level of durable suppression (proportion on ART who have been suppressed for a year). Our source included recent estimates for (1) by race and by age, but not the interaction of the two. We used a weighted average of their 18–29 and 30–39-year-old data and assumed that the overall prevalence ratio by race that they observed for each outcome held within this age group as well. This suggested that 30% of young Black MSM who were diagnosed were in care, and 74% of those were on ART, for a combined value of 22% of young Black MSM who were diagnosed being on ART at any time point. Analogous figures for young White MSM were 47%, 84% and 39%. For (3), we used the same method of deriving estimates specific to young Black MSM (47% of those on ART are durably suppressed) and young White MSM (60% for the corresponding figure). For (2), we used figures by race from the same paper; however, similar figures by age were not included. Instead, we adjusted by using the relative rates of retention in care and suppression for young adults (25-44) compared to all respondents from an additional analysis of the care continuum for members of all risk groups (not just MSM-specific) in the US.29 This yielded estimates for the percent of young MSM on ART who are virally suppressed of 62% for Blacks and 68% for Whites.

None of these three sets of values entered the model directly as inputs. Parameter (3) was converted into a per-time step probability of falling out of suppression, by using the inverse geometric function to calculate the probability consistent with observed levels of durable suppression after 1 year. Our other two input parameters were the proportion of those initiating ART who achieved full suppression, and the per-time step probability of re-achieving suppression after one had previously fallen out. We simulated our full model iteratively until we identified the unique values of these parameters by race that yielded the values estimated for parameters (1) and (2) above. The resulting set of model inputs were:

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Black** | **White** |
| Proportion of those initiating ART who achieved full suppression | 0.614 | 0.651 |
| Per-week probability of falling out of suppression | 0.0102 | 0.0071 |
| Per-week probability of re-achieving suppression | 0.00066 | 0.00291 |

This study averaged over the race-specific parameter estimates because race was not explicitly modeled in this study.

## 6.4 Disease Progression and Mortality after ART Initiation

Mortality after ART initiation was modeled based on the cumulative time on and off ART for persons who were fully or partially suppressed. The maximum time between infection and the start of AIDS was 9.7 years.20 If a person in either the full or partial suppression categories who spent this much time off ART during the course of infection progressed to AIDS. For the partially suppressed, we assumed a maximum time on ART of 15 years, similar to previous models, to account for treatment failure.1 For this group, the time to AIDS was an additive function of two ratios: (time on treatment / maximum time on treatment) + (time off treatment / maximum time off treatment). AIDS was simulated to occur when the sum of this score exceeded 1. Persons who had ever initiated ART progressed through AIDS at a similar rate as those who were ART-naïve.

# 7 HIV INTERHOST EPIDEMIOLOGY

Interhost epidemiological processes represent the HIV-1 disease transmission within the model. Disease transmission occurs between sexual partners who are active on a given time step. This section will describe how the overall rate as a function of the intrahost epidemiological profile of each member of a partnership, and behavioral features within the dyad.

## 7.1 Disease-Discordant Dyads

At each time step in the simulation, a list of active dyads was selected based on the current composition of the network. This was called an “edgelist.” Given the three types of partnerships detailed above, the full edgelist was a concatenation of the type-specific sub lists. The complete edgelist reflects the work of the STERGM- and ERGM-based network simulations, wherein partnerships formed on the basis of nodal attributes and degree distributions (see Section 2). Dyads were considered active at a specific time step if the terminus of that simulated edge was greater than or equal to the current time step (right-censored). From the full edgelist, a disease-discordant subset was created by removing those dyads in which both members were HIV- or both were HIV+. This left dyads that are discordant with respect to HIV status, which was the set of potential partnerships over which a HIV infection may be transmitted at that time step.

## 7.2 Per-Act HIV Transmission Probability

Within disease-discordant dyads, HIV transmission was modeled based on a sexual act-by-act basis, in which multiple acts of varying infectiousness could occur within one partnership within a weekly time step. Determination of the number of acts within each discordant dyad for the time step, as well as condom use and role for each of those acts, was described in Sections 2 and 3. Transmission by act was then modeled as a stochastic process for each discordant sex act following a binomial distribution with a probability parameter that is a multiplicative function of the following predictors of the HIV- and HIV+ partners within the dyad.

|  |  |  |  |
| --- | --- | --- | --- |
| **Predictor** | **Partner** | **Parameters** | **References** |
| Sexual role (insertive or receptive) | HIV- | *Receptive:* 0.008938 base probability when HIV+ partner has 4.5 log10 viral load | Vittinghoff30 |
| *Insertive:* 0.003379 base probability when HIV+ partner has 4.5 log10 viral load | Vittinghoff30 |
| HIV viral load (VL) | HIV+ | Multiplier of 2.45(VL - 4.5) | Wilson31 |
| Acute stage | HIV+ | Multiplier of 6 | Leynaert19, Bellan32 |
| CCR5 status | HIV- | Δ32 homozygote: multiplier of 0 | Marmor15 |
| heterozygote: multiplier of 0.3 | Marmor15 |
| Condom use | Both | Multiplier of 0.25 | Varghese33, Weller34 |
| Circumcision status | HIV-, insertive | Multiplier of 0.40 | Gray14 |

For each act, the overall transmission probability was determined first with a base probability that was a function of whether the HIV- partner was in the receptive or insertive role, with the former at a 2.6-fold infection risk compared to the latter. The HIV+ partner’s viral load modifies this base probability in a non-linear formulation, upwards if the VL was above the VL set point during chronic stage infection in the absence of ART, and downwards if it was below the set point. Following others, we modeled an excess transmission risk in the acute stage of infection above that predicted by the heightened VL during that period. Three predictors of the HIV- partner could reduce the risk of infection: the Δ32 allele on the CCR5 gene, condom use within the act, circumcision status (only if the HIV- partner was insertive in that act).

The final transmission rate per partnership per weekly time step was a function of the per-act probability of transmission in each act and the number of acts per time step. The per-act transmission probability could be heterogeneous within a partnership due to various types of acts in each interval: for example, a HIV- man who is versatile in role may have both insertive and receptive intercourse within a single partnership; some acts within a partnership may be protected by condom use while others are condomless. Transmission was simulated for each act within each serodiscordant dyad, based on draws from a binomial distribution with the probability parameter equal to the per-act transmission probabilities detailed above.

# 8 STI TRANSMISSION

## 8.1 Overview of Model Structure

Directional transmission of NG and CT was modeled between sexual partners who were sexually active during a given time step. At each time step, a list of active dyads (the “edgelist”) was selected based on the current composition of the network. This edgelist concatenated the three types of partnerships included in the network simulations: main, casual, and one-off. Dyads were considered active at a time step if the terminus of that simulated edge was greater than or equal to the current time step.

We created a disease-discordant subset of the edgelist for NG and CT at each time step by removing dyads in which both members had the disease of interest or neither had the disease of interest. This left dyads discordant with respect to, respectively, NG and CT infection status, which was the set of potential partnerships in which the infections could be transmitted at that time step.

NG and CT were modeled with susceptible-infected-susceptible (SIS) dynamics, with no immunity. Site-specific transmission of NG and CT was modeled on a sexual act-by-act basis, in which multiple acts of varying infectiousness could occur within a partnership within a weekly time step. The number of anal sex acts per week for each ongoing relationship was determined from a random draw from a Poisson distribution, with the lambda (event rate) parameter of the distribution specific to the partnership type.4 For one-time contacts, the number was set deterministically to 1 for the time step in which it occurred.

For site-specific disease transmission to occur, the sexual position of partners within an MSM anal intercourse dyad was considered. For example, receptive AI with a partner infected with a urethral STI was necessary for an individual to become rectally infected. Dual-site and dual-disease infection was possible, such that a man could have had, for example, rectal NG and rectal CT infection, rectal NG and urethral CT, or rectal NG and urethral NG concurrently. We modeled disease transmission by act as a stochastic process for each discordant sex act, which followed a binomial distribution with a probability parameter that was a multiplicative function of the base transmission probability and condom use.

## 8.2 STI Co-Factor Effect on HIV Transmission Probability

We modeled an increased HIV transmission risk from a current STI status, in that a receptive HIV- partner with a rectal STI or an insertive HIV- partner with a urethral or STI would have an increased risk of HIV transmission from a HIV+ partner compared to not having a STI present. Chesson et al.35 described this effect for several STIs. Starting with a baseline HIV transmission probability per sex-act of 0.001 (95% CI: 0.0005–0.0015), they estimated a 10-fold (95% CI: 5–15) increase in per-act HIV transmission probability, to 0.014 (95% CI: 0.01–0.05), in the presence of NG infection. For CT infection, they estimated a 5-fold increase (95% CI: 3–15) in per-act HIV transmission probability to 0.0078 (95% CI: 0.003–0.01). Vaughan et al.36 found that the hazard ratio for existing rectal NG or CT infection on HIV seroconversion was 2.7 (95% CI:1.2–6.4), and Pathela et al.37 estimated a similar risk ratio for the effect of rectal NG or CT infection on HIV transmission, which was slightly elevated over estimates not taking site-specific infection into account.38 Using these estimates, we established a Bayesian prior distribution of 1.50–3.00 for the relative increase in per-act HIV acquisition risk for rectal STI infections, and 1.00–2.50 for urethral STI infections. These estimates incorporate site-specific infection and assume an increased risk associated with rectal infection. After model fitting, the estimated posterior multiplier values for risk of HIV acquisition were 2.175918 for NG or CT at a rectal site, and 1.564797 for NG and CT at a urethral site.

## 8.3 Chlamydia Transmission Probability

Estimated values of the per-sex-act CT transmission risk in previous STI-only and HIV/STI models have depended on whether the infection was symptomatic, the type of sex act, as well as the role and position of the infected partner. The baseline per-act CT transmission risk for heterosexual encounters has been estimated in multiple models, with the middle 50% of per-act probability estimates describing MTF transmission clustered between 0.09–0.2039–53 with a wider range of 0.025 to 0.6.54–61 Estimated per-act transmission risk was generally higher in non-main partnerships when models incorporated or characterized different risk estimates by partnership types.49 Per-partnership transmission risk estimates ranged widely from 0.09 to 0.7,43,62–65 and per-day infection probabilities ranged from 0.001571 to 0.154, with higher estimates for casual partnerships relative to main partnerships.66–69 In models where the direction of transmission was reported, the estimated per-act FTM CT transmission probability varied, commonly estimated as 0.5–0.8 times the MTF CT transmission probability,40,45,46,53,54,56,67 although some models did estimate that the FTM transmission probability was greater.39,68

For our model, we focus on the baseline male-to-male CT transmission risk through anal intercourse in STI and HIV/STI models. Fewer models and estimates of this probability exist for MSM than do for heterosexual populations. Estimates of the per-act transmission probability have included 0.1–0.24,70 0.4 for receptive AI,71 0.32 for insertive AI,71 and 0.35 per-partner.72 With greater uncertainty around these parameters, we established a prior distribution of 0.10–0.60 for the per-act rectal CT transmission likelihood, and a distribution of 0.10–0.50 for urethral CT transmission to incorporate site-specific infection. The estimated posterior means were 0.2494 for per sex-act rectal CT transmission probability and 0.1944 for per sex-act urethral CT transmission probability. We also include a multiplier of 0.30 for the effect of condom usage on CT transmission probability to reflect the decreased probability of transmission in protected sex acts, consistent with the literature.73,74

## 8.4 Gonorrhea Transmission Probability

Estimates of the NG transmission risk per sex-act have been diverse in HIV/STI models and STI-only models, depending on the type of sex act as well as the role and position of the infected partner. This baseline per-act risk has been estimated in a number of models, with the middle 50% of estimates of the per-act risk from MTF transmission models located between 0.20 and 0.60,39,40,45–48,53–55,57,60,63,75–85 with an outer range of 0.1 to 1.82,86,87 Per-day infection probability estimates ranged from 0.011 to 0.6,67,77,88 with higher probabilities estimates for non-main partnerships. Per-partnership estimates differed widely, ranging from 0.10 to 0.80.56,89,90 When FTM transmission was distinguished, the per-act39,40,45,46,56,67,75,76,78,82–84,89 and per-partnership54,90 estimated risk tended to be decreased or halved, compared to the MTF risk, with some exceptions in which the FTM risk was estimated to be greater.53,78,85

Compared to CT infection, the baseline transmission probability per sex-act for male-male anal intercourse in STI models has been better characterized for NG infection. Estimates of these risks have ranged widely from 0.02 and 0.8,71,72,91–94 with greater risks assumed for receptive anal intercourse compared to insertive anal intercourse. To account for the uncertainty in this parameter estimate, we established a prior distribution of 0.10–0.60 for the per-act rectal NG transmission likelihood, and a distribution of 0.10–0.50 for urethral NG transmission to incorporate site-specific infection. Bayesian calibration generated posterior values of 0.5364 for per sex-act rectal NG transmission probability and 0.4347 for per sex-act urethral NG transmission probability. Like CT, we also included a multiplier of 0.30 for the effect of condom usage on NG transmission probability to reflect the decreased probability of transmission in protected sex acts.

# 9 STI SYMPTOMS AND TREATMENT

## 9.1 Treatment

Testing and treatment for NG and CTs was a function of whether the infection was symptomatic or asymptomatic. Treatment status was assigned stochastically among those with either symptomatic or asymptomatic NG or CT infection acquired prior to the current time step. Following empirical data, we simulated that 90% of men with NG and 85% of men with CT who have symptomatic infection successfully sought and completed treatment.95 Symptoms-driven testing was correlated, in that a man presenting with rectal symptoms was tested for both NG and CT at a rectal site. We assumed that treatment entailed sufficient antibiotic dosage to fully treat the infection. Additionally, we assumed that, for men with concurrent infection by the same bacterial STI at both rectal and urethral sites, treatment at one anatomic site would result in effective treatment at the other anatomic site. There are some data suggesting that certain antibiotics may be less effective at treating the bacterial STI at some anatomic sites, which may be a potential limitation for those modeled individuals who have concurrent dual site infection.

The average time on treatment/in recovery was 1 week for NG and CT, with a stochastic recovery process described below. A background screening process for the identification of asymptomatic infection was newly implemented, with more details in Section 11. Any individual who had been sexually active, e.g. in an edgelist in a non-dissolved partnership, in the previous year was eligible for screening. Screening was implemented as a deterministic process for each STI, stratified by HIV serostatus, with a certain proportion of individuals who met eligibility criteria screening every 365 days for both NG and CT. We explored imperfect adherence to asymptomatic screening and associated treatment for any identified asymptomatic infection in a sensitivity analysis of treatment completion for asymptomatic infections, varying completion of an assigned screen/treat from 0% to 100%.

A flow diagram showing the trajectories of STI testing and treatment off PrEP is shown in Figure S1. The site of infection influenced the symptomatic status of a given infection, with rectal infections more likely to be asymptomatic and urethral infections more likely to be symptomatic.96 The symptomatic status of an infection was assigned stochastically from a binomial distribution at the time of infection according to site-specific and infection-specific probability parameters for symptomatic status. Treatment of asymptomatic infection required diagnosis through the screening process that is described further in Section 11.

**Figure S1.** Schematic Flow Diagram of STI Testing and Treatment



## 9.2 Chlamydia Symptoms

The asymptomatic nature of some CT infections can have an impact on the risk of transmission, as well as the dynamics of spread in a population. These estimates have varied widely for CT. For men, the middle 50% of estimates of the proportion of infections that are symptomatic from STI or HIV/STI models has ranged from 0.3–0.5,39,42,45,50,53,54,57,60,64,65,69,70,75 with an outer range of 0–0.7541,44,48,97,98 and a sizable cluster of estimates at 0.75.58,59,67,68,72 Beck et al.71 differentiated between the probability of symptoms of urethral and rectal CT infections in MSM, estimating a 4-fold increase in the likelihood of symptoms (0.58 versus 0.14) at the urethral site. The proportion symptomatic in males tends to be increased 1.5–3 fold over the same proportion in women,39,41,42,45,50,53,54,64,65,67–69,75 with a few exceptions where women are estimated to be more symptomatic.44,60,98 In our prior STI model5, we used a Bayesian approach to address uncertainty, establishing a prior distribution for calibration of 0.01–0.15 for the probability that a rectal CT infection would be symptomatic, and a distribution of 0.60–0.95 for the probability that a urethral CT infection would be symptomatic to incorporate site-specific infection. These estimated posterior values were 0.1035 for the probability of symptomatic rectal CT, and a probability of 0.8850 for symptomatic urethral CT. For this model, however, we reverted to the Beck values of 0.14 for the probability of symptomatic rectal CT infection and 0.48 for the probability of symptomatic urethral CT infection (the Beck value subtracting a correction of 0.10 to account for references focusing on participants attending STD clinics), increasing the probability of symptoms at a rectal site but decreasing the probability of symptoms at a urethral site.

## 9.3 Gonorrhea Symptoms

NG infections can also be present with or without symptoms and estimates of the proportion of infections that are symptomatic have varied. The middle 50% of estimates of this proportion from STI or HIV/STI models for men has ranged from 0.35–0.88,39,45,57,60,75,77,83,87,92,93 with a lower quartile of 0.11 to 0.2548,54,82,97 with a sizable group of estimates between 0.9 to 0.95.53,67,72,90,99 Beck et al.71 differentiated between the probability of symptoms of urethral and rectal NG infections in MSM, estimating a nearly 6-fold increase in the likelihood of symptoms (0.90 versus 0.16) at the urethral site. The proportion symptomatic in males tends to be increased 1.5–3 fold over the same proportion in women for NG.39,45,53,54,67,75,82,83,87,90,99 In our prior STI model5, we used a Bayesian approach to address uncertainty, establishing a prior distribution of 0.01–0.15 for the probability that a rectal NG infection would be symptomatic, and a distribution of 0.60–0.95 for the probability that a urethral NG infection. These generated posterior values of 0.0770 for the probability of symptomatic rectal NG, and 0.8244 for the probability of symptomatic urethral NG. As with CT, these reflect an increased likelihood of symptomatic urethral infection, which could be due to easier detection at a urethral site. For this model, however, we reverted to the Beck values of 0.16 for the probability of symptomatic rectal NG infection and 0.80 for the probability of symptomatic urethral NG infection (the Beck value subtracting a correction of 0.10 to account for references focusing on participants attending STD clinics), increasing the probability of symptoms at a rectal site but decreasing the probability of symptoms at a urethral site.

# 10 STI DURATION AND RECOVERY

We modeled recovery from NG or CT according to whether men were treated for their infection. Recovery from infection back to susceptibility could occur through natural clearance of each infection or through effective antibiotic treatment. Recovery from untreated NG or CT infection was simulated as a stochastic process among those whose infection, whether symptomatic or asymptomatic, had been present for a duration of time greater than the natural history of asymptomatic infection. The probability of recovery per time-step for symptomatic and asymptomatic untreated infection was the reciprocal of the duration of infection. Recovery from treated NG or CT infection was a stochastic process based on draws from a binomial distribution among those treated for their infection, occurring with a per-time-step probability equal to the reciprocal of the duration of the length of treatment. Upon recovery, individuals were immediately susceptible to reinfection.

## 10.1 Duration of Chlamydia Infection

Estimates of the duration of CT infection have varied broadly depending on whether the infection was symptomatic. STI and HIV/STI models have generally estimated the duration of symptomatic CT infection in men primarily as 30–35 days,41–44,50,51,59,65,67,68 but some models have estimates closer to 13–14 days for treated men57,64,71 or at a higher range between 112–365 days.45,53,54,71 Models which have not specified whether the infection is symptomatic or asymptomatic have widely divergent estimates ranging from 60 days up to 370 days.49,52,61,66,72,100,101 Some models specify the length of an infectious stage ranging from 3 weeks in treated infection up to 457 days,47,75 while Welte et al. estimate the incubation time of CT as 12 days.43

For models specifying the duration of an asymptomatic CT infection, estimates tend to cluster between 200–240 days41–43,50,53,57,67,68,70 and 433–497 days.51,59,69,102 Some models estimated 180 days,44,64 365 days,65 or 622 days,39,45 reflecting a range of uncertainty. Beck et al.71 have estimated 240 days for urethral infection and 497 days for rectal infection. Given this uncertainty, we established a prior distribution of 26–65 weeks for the duration of asymptomatic rectal or urethral CT infection. These resulted in posterior values of 44.28 weeks, or about 310 days, for the duration of asymptomatic CT infection, consistent with our previous STI model.5

## 10.2 Duration of Gonorrhea Infection

Estimates of NG duration have also varied widely depending on whether the infection was symptomatic. STI and HIV/STI models have modeled the duration of symptomatic NG infection as bimodal, with some estimates as low as 12–13 days,57,67,71,78,90, generally for treated or care-seeking persons, and others between 105–185 days, including for untreated symptomatic infection.39,45,53,71 Models which have not specified whether the infection is symptomatic or asymptomatic have widely divergent estimates of duration, ranging from 10–60 days72,80,81,84–86,103 to 330–365 days82,100 with estimates also observed at 30-day intervals between 60 days and 200 days.54,89,93,103 Estimates of the duration of the infectious stage of NG ranged from 14 days in treated individuals6 to 180–185 days in untreated individuals71,79,83 but varied widely between those extremes.47,75,76,99

For models specifying the duration of an asymptomatic NG infection, estimates were also bimodal, with clusters at 105–135 days39,45,53,67 and 180–185 days.57,90 Beck et al.71 have estimated 240 days for urethral infection and 300 days for rectal infection. Given this uncertainty, we established a prior distribution of 15–52 weeks for the duration of both asymptomatic rectal and asymptomatic urethral NG infection. The estimated posterior means were 24.79 weeks, or about 175 days, for the duration of asymptomatic rectal and urethral NG infection, consistent with our previous STI model.5

# 11 STI SCREENING

A background screening process for the identification of asymptomatic infections was newly implemented. Any individual who had been sexually active, e.g. in an edgelist in a non-dissolved partnership, in the previous year was eligible for screening. Screening was implemented as a deterministic process for each STI, stratified by HIV serostatus, with a certain proportion of individuals who met eligibility criteria screening every 365 days for both NG and CT.

## 11.1 STI Screening Indications and Screening Eligibility

STI screening was simulated following CDC’s guidelines104, which indicate sexually active MSM for site-specific testing at sites of sexual contact at least annually, irrespective of condom use, and more frequent screening (every 3-6 months) “if at increased risk.” Men were dynamically evaluated every 6 months and having more than one partner in the 6 months prior to assessment made a man eligible for more frequent (higher-risk) screening. Exhibiting sexual activity in the prior year, but not more than one partner in the last 6 months, made a man eligible for annual screening. This partner cut-off over the 6-month look-back period was varied in a secondary analysis.

## 11.2 STI Screening Process

Men were reassessed every 6 months and classified as being eligible for different screening trajectories (annual for sexually active, semiannual for higher-risk) depending on their indications. This process established the denominators for higher-risk screening, in that all men who had more partners in the last 6 months than the cut point threshold were included in the denominator for coverage of higher-risk screening.

Coverage of higher-risk screening: $\frac{Men assigned to test semiannually}{All men with more than X partners in prior 6 months}$

This was a dynamic process, dependent on the existing coverage of the higher-risk screening trajectory. If the fixed coverage level for higher-risk screening (e.g. 10% of all eligible) because, men could then be initiated to start screening on a semi-annual basis, contingent on retaining their eligibility at subsequent evaluations, until the coverage level was reached. Once the coverage level was reached, no more men were recruited for screening until the level fell below that set value. Screening was implemented as a deterministic process for each STI, stratified by HIV serostatus, with a certain proportion of individuals who met eligibility criteria for screening every 365 days for both NG and CT.

The denominator for the population eligible for sexually active screening changed because of those assigned to a higher-risk testing trajectory, in that those eligible but not selected for higher-risk screening could still be eligible to test annually. In practice, this meant that as the coverage of higher-risk screening decreases, the denominator for coverage of sexually active screening increases. Thus, to maintain the fixed level of sexually active screening coverage, more eligible individuals would then be assigned to test annually.

Coverage of sexually active screening: $\frac{Men assigned to test annually}{All men sexually active in prior year not otherwise assigned to test semiannually}$

This too was a dynamic process, dependent on the existing coverage of the sexually active screening trajectory. If the fixed coverage level for sexually active screening (e.g. 10% of all eligible) was not reached, men in the sexually-active risk group could then be initiated to start testing on an annual basis, contingent on retaining their eligibility at subsequent evaluations, until the coverage level was reached. Screening was implemented as a deterministic process for each STI, stratified by HIV serostatus, with a certain proportion of individuals who met eligibility criteria for screening every 365 days for both NG and CT. We explored imperfect adherence to asymptomatic screening and associated treatment for any identified asymptomatic infection in a sensitivity analysis of treatment completion for asymptomatic infections, varying completion of an assigned screen/treat from 0% to 100%.

We selected 44% of sexually active HIV-negative MSM in the model to test regularly on an annual basis for gonorrhea and chlamydia, respectively, and 61% of sexually active HIV-positive MSM in the model were chosen to test regularly on an annual basis for gonorrhea and chlamydia respectively.105 These values were selected to be slightly lower than empirical data (Table S1) from NHBS on NG and CT testing in the prior 12 months to allow for symptoms-based testing to boost the overall proportion of those who had tested for a particular STI in the past 12 month to empirical levels.106,107

|  |
| --- |
| Table S1: Testing targets for calibration |
|  | HIV-negative MSM | HIV-positive MSM |
| Statistic | Tested for gonorrhea in the past 12 months | Tested for chlamydia in the past 12 months | Tested for gonorrhea in the past 12 months | Tested for chlamydia in the past 12 months |
| Target | 45.8% | 45.8% | 64.1% | 62.8% |
| Source | 107 | 107 | 107 | 107 |

## 11.3 Testing Adherence and Progression to STI Treatment

Positive diagnoses resulted from the presence of an active STI at the time at which screening occurred, and all diagnosed men progressed to treatment, though a sensitivity analysis varied the probability of effective treatment among those screened.

# 12 EXPEDITED PARTNER THERAPY

## 12.1 EPT Indications and Eligibility

An expedited partner therapy process for providing medication to index partners to give to their partners was newly implemented. Men with NG or CT infection were dynamically assessed at the time of diagnosis. An index patient, one getting diagnosed and treated for a NG or CT infection, was eligible to receive medication to provide to their recent sexual partners for the same infection with which the index patient was diagnosed (either NG or CT). Any index patient with a sexual partner in the prior 60 days was eligible to receive the medication, and any partner in the prior 60 days could receive that medication from the index patient. The EPT processes were implemented as a continuum. Partners could receive EPT only at the time step following index diagnosis, and partners already being treated for that STI could not receive EPT. A secondary analysis varied the duration of this look-back period, increasing and decreasing the length of time prior to index patient diagnosis during which sexual activity made a partner eligible for EPT (the EPT partnership window). Base EPT implementation values for each continuum step modeling parameter are listed in Table 1 in the main paper, and in Section 13.2 below. Unless noted, these modeling parameter values are held fixed at base values when another modeling parameter is being varied. In the following sections, we describe how EPT was implemented to follow the steps of the proposed EPT continuum (Figure 1 in the main paper)**.**108

## Coverage (Provision to Index Partner)

In the continuum structure governing EPT implementation in this model, provision of EPT medication for a NG or CT infection from a provider to an index patient at the time of diagnosis is referred to as “coverage.”

EPT Coverage: $\frac{Men diagnosed with NG or CT receiving EPT medication}{Men diagnosed with NG or CT and had partners in the past 6 months}$

Men were reassessed dynamically at the time of diagnosis with NG or CT infection. The denominator at each time step was comprised of men who: 1) were diagnosed with NG or CT at that time step; 2) were sexually active (e.g. had had at least 1 partner in the last 6 months). Set to zero in our reference, no-EPT model, we vary EPT coverage from 10% - 100% as a primary analysis and explored variations in coverage and provision to specific partnership types, such as any index being able to receive medication but only being able to distribute it to certain types of partners.

 Previous EPT trials and analyses have reported a variety of measures of coverage, both from a patient perspective as well as a provider perspective. These include results from heterosexual men and women and MSM. A small MSM trial evaluating patient-delivered partner therapy (PDPT) alongside an online web notification system enrolled 19% of patients who were offered enrollment.109An analysis of STD Surveillance Network (SSuN) data found that only 5.6% of patients diagnosed with gonorrhea reported receiving EPT, and that only 2.6% of MSM (ranging from 0.08% in New York to 13.2% in Baltimore) had received EPT.110 Two analyses in New York City found that 30.5% of young women with chlamydia had received EPT for partners111, while 55.9% of index males attending STD clinics had accepted EPT when offered, a figure growing to 69.4% after excluding patients whose partners had already been treated or were in the clinic to be treated*.*112A 2004-2005 trial of population-based PDPT implementation in King County, Washington increased the percentage of cases receiving PDPT from a diagnosing clinician from 5.6% to 16%113*,* while a more recent statewide community-level trial of PDPT in Washington State increased PDPT receipt from 18% to 34% (4.7% to 16.6% among males).114 This latter trial increased the proportion of providers who offered PDPT frequently to patients that they did not refer for partner services from 29.3% to 80.9%.

In a national provider survey in the mid-2000s, around half (49.3% for chlamydia and 56% for gonorrhea) reported ever using PDPT, while a smaller fraction (14.4% for chlamydia or 11.3% for gonorrhea) reported using PDPT frequently.115That same analysis estimated that 8.8%-14.6% of total GC cases get PDPT, while 13.1-20.3% of total CT cases get PDPT. A similar analysis of providers in New York City found that about half of them had ever used PDPT, while more than two-thirds of providers reporting frequent partner referral reported ever having using PDPT.116 Given the nature of the research question and primary analysis, we evaluated a range of possible scenarios. We selected, as a base value for analyses of other steps of the EPT continuum, a coverage of 20% for providers giving EPT medication to sexually active index patients.

## 12.3 Provision (Provision to Non-Index Partner)

In the continuum structure governing EPT implementation in this model, provision of EPT medication for a NG or CT infection from an index patient to their recent non-index partners in the week following diagnosis is referred to as “provision.”

EPT Provision: $\frac{Partners receiving EPT medication from a newly diagnosed index patient}{Partners of newly diagnosed index patients in the past 60 days}$

All recent sexual partners of a newly diagnosed index patient were eligible to receive medication for the infection with which the index patient was diagnosed (NG or CT). Provision likelihood differed by partnership type (main, casual, or one-time) and, for main or casual partnerships, by whether the relationship was ongoing or had ended. This was intended to address decreased likelihood of being able to provide medication to past partners and less connected partners. Set to zero in our reference, no-EPT model, we varied EPT provision from our baseline levels up to a 50% relative increase. In secondary analyses, we also explored variations in provision to specific partnership types, such as any index being able to receive medication but only being able to distribute it to certain types of partners.

Previous EPT trials and analyses have reported a variety of measures for provision of medication to partners, ranging from simple partner notification to number of partners provided with medication, over several different timepoints. These include partnership type-specific results, as well as results from heterosexual men and women and MSM. An Australian trial of partner notification among MSM found that 78% of index MSM contacted partners, resulting in 82.4% of regular partners and only 8.9% of casual partners being contacted.117

In a multicenter trial of women diagnosed with chlamydia, 85% of women with one partner gave that partner PDPT and/or a referral sheet.118A small trial of Scottish women diagnosed with chlamydia found that 94% of women receiving PDPT reported contacting all partners and the additional 6% contacted some (mean = 1.3 partners).119 In a mid-2000s trial in Washington state, 71% of EPT patients agreed to give medication to at least one partner, with 93% (NG) and 90% (CT) of those patients actually obtaining medication for their partners.120 In the more recent statewide community-level trial, 92.6% of patients reported giving a PDPT pack to at least one sex partner.114In a small trial among MSM, index patients receiving PDPT notified an average of 3.37 partners (95% CI: 2.72 – 4.17), compared to 2.70 partners in the no PDPT arm.109A secondary analysis of PDPT trial data for male urethritis and female trichomoniasis found that 70.6% of men disclosed a potential STD exposure to partners, compared to 49.1% in the partner referral arm, and 90.3% of women disclosed a potential STD exposure to partners, compared to 87.8% in the partner referral arm.121

A recent trial of EPT for Peruvian MSM evaluated measures over a 14-day time period. Across PDPT and control arms, notification of at least one partner in 2 weeks was 71.6% (111/155), with a median of 1 partner notified per participant.122 In the EPT arm, 83.1% of index patients reported notifying at least one partner, compared to 58.3% in the standard partner notification arm, and the proportion of all recent partners notified (53.5%) was significantly greater in the EPT arm than in the control arm (34.7%). Additionally, 80% of stable male partners in the PDPT arm were notified, compared to 54.8% of casual partners in the PDPT arm.

Given the nature of the research question and primary analysis, we evaluated a range of possible scenarios. Taking some of the findings from the Peruvian trial, as well as input from subject matter experts, we allowed the provision of medication to differ by partnership type and by whether the partnership was ongoing. We selected, as base values for analyses of other steps of the EPT continuum, provision likelihoods of 50% to main, ongoing partners, 40% to main, ended partners, 40% to casual, ongoing partners, 30% to casual, ended partners, and 20% to one-time partners.

## 12.4 Uptake (Uptake by Non-Index Partner)

In the continuum structure governing EPT implementation in this model, uptake of EPT medication for a NG or CT infection by a non-index partner who had received medication from a newly diagnosed index patient is referred to as “uptake.”

EPT Uptake: $\frac{Partners taking the medication}{Partners receiving medication from index patients}$

Uptake likelihood could differ by partnership type (main, casual, or one-time), but, due to lack of substantial evidence, was kept equal across partnership types. Set to zero in our reference, no-EPT model, we varied EPT provision from our baseline levels up to a 20% relative increase.

Previous EPT trials and analyses have reported a variety of measures for uptake of medication by partners. These include results from heterosexual men and women and MSM. Additionally, many of these trials only report patients being treated, which likely reflects a combination of provision of medication to partners and uptake of the medication by partners, or use self-report data from the index case.

A small study presenting hypothetical scenarios to MSM found that about half of partners would accept EPT following notification of potential STD exposure by a partner with which the index had been a condomless, receptive anal sex partner.123Trials in Seattle (61%)120 and New Orleans (55.8%)124 reported that more than half of partners of cases receiving EPT had told the index patients that they had taken the antibiotics.A Washington PDPT trial collecting data from index cases receiving EPT about whether their partners were “very likely to have been treated” showed that 83% of partners in ongoing relationships, 58% of partners in ended relationships, and only 36% of partners in relationships lasting a single day were very likely to have been treated.125 A Scottish trial among young women with chlamydia found that 42% of partners were confirmed as tested and treated109, while 79.5% of a similar population in New York City receiving EPT reported treatment of partners.111 An analysis of New York City pharmacy data found 0.2 partner treatments per index patient, dropping to 0.07 treatments per index after excluding a large pharmacy.126

In a small PDPT trial among MSM, the ratio of unadjusted means between the EPT and control arms was 1.53, with EPT recipients having, on average, 2.33 partners (1.84 – 2.96) partners treated.109In an early PDPT trial (1998-2003) among men and women in Washington state, 61% of index patients (519/850) said all partners were “very likely” to have been treated or tested negative for STIs, compared to 49% in the standard partner referral arm.120 From the partner perspective, 77% of partners were notified by the patient, tested negative, or treated, equivalent to 78% in the standard partner referral arm. In another Washington trial (2004-2005), the percentage of index cases for whom all partners were treated increased from 39% to 58% following population-based EPT implementation, with nearly three-quarters of partners for whom index cases accepted PDPT were treated.113

Given the nature of the research question and primary analysis, we evaluated a range of possible scenarios. We selected, as base values for analyses of other steps of the EPT continuum, uptake likelihoods of 80% among main partners provided with the medication (ended or ongoing), 80% among casual partners provided with the medication (ended or ongoing), and 80% among one-time partners provided with the medication.

## 12.5 Treatment Success (EPT Adherence and Progression to STI Treatment)

We selected, as a base value for analyses of other steps of the EPT continuum, a treatment success/adherence probability of 100% among partners taking the medication, meaning that every partner taking EPT was treated effectively. In the future, we hope that this parameter may account for factors such as potential NG treatment failure or the differential effects of EPT dosages or regimens.

## Other Statistics Relevant to EPT

Other data points outside of the EPT continuum that are relevant to EPT were reported in these trials and other studies. These results may influence or further describe the EPT continuum or inform further implementation, such as care-seeking following receipt of EPT medication. A small EPT trial among MSM evaluated intention to seek care. If given medication by their partner, compared to being given the medication by a provider, around 40% were more likely to be treated for the STD or tested by HIV or syphilis, while 11% and 13% were less likely to be treated for the STD or tested for HIV or syphilis, respectively.123When given these hypothetical scenarios, 85% of men being notified by a partner reported that they would notify their other partners, thus reaching secondary contacts of an index case. In a small trial of PDPT among MSM, the ratio of unadjusted means comparing the PDPT arm to the no-PDPT arm was 0.55 for HIV testing and 0.88 for syphilis testing, meaning that partners receiving PDPT were less likely to pursue other testing or seek care.109 The mean time to dispensation of medication to partners was measured as 3.1 days (SD = 8.7 days) for patients with chlamydia and both chlamydia and gonorrhea, and 6.1 days (SD = 9.2 days) for patients with gonorrhea in one trial.120

The reinfection risk or rate of index patients in EPT trials has also been a measure of interest, spanning a variety of different time periods.In one year in a San Francisco EPT trial, 18.57% of index patients were reinfected with chlamydia, with 15.75% reinfection among MSM with chlamydia*.*127At follow-up in a trial of women diagnosed with CT, 11% and 10% were reinfected among those providing and not providing PDPT to partners, respectively118*,* while similar proportions wereobserved in a trial among women with chlamydia attending family planning clinics in New Orleans (11.5%)128 and men in Washington state (7%)*.*120In the Peruvian MSM trial, 91% STI prevalence at baseline was reduced to 2.4% two weeks later.122

One concern surrounding EPT is missed opportunities for HIV and STI treatment. A few papers have looked at the prevalence of STIs in partners. One Australian analysis looked at sexual contacts of diagnosed gonorrhea or chlamydia cases, including MSM, and found that 13.8% of MSM were diagnosed with HIV or a bacterial STI different from the one that their partner had presented with.129

Among those partners, 5.3% had a new HIV diagnosis. Looking at secondary contacts for all people evaluated (not just MSM), 28-29% of contacts were contacted, and it was estimated that between 3 and 7% of secondary contacts who need chlamydia treatment would be missed. A similar analysis using data from US STD clinics found that partners of index patients without detected infection were at high risk for STIs, and their infections often differed from the index partner.130Another aspect of missed opportunities relates to care-seeking among those receiving EPT. In one of the larger EPT trials in New Orleans, 13.7% of index cases came to the clinic because they were contacts of a known infected person, 87.6% reported that they could contact the partner if they wanted to at baseline, and a slightly smaller fraction (8.4% in PDPT arm vs 12.7% in standard partner referral arm) had unprotected sex prior to the partner taking any medication.124 93% of those who would not take PDPT would seek care in a hypothetical scenario with asymptomatic infection and condomless insertive anal sex, compared to 84% among those who would take PDPT.123 If symptomatic, virtually all (99% and 97%, respectively) reported intention to seek care. An analysis looking at patients refusing EPT in a NYC STD clinic found the most common reasons were: partner already in clinic today to be treated (26.3%), partnership had ended (25%), partner already treated (20.3%), and a preference for medication to be delivered by the clinician (19.6%).112

# 13 MODEL CALIBRATION AND PARAMETER ESTIMATION

This section describes the methods for executing the simulations and conducting the data analysis on the outcomes in further detail.

## 13.1 Model Calibration

Starting with a population of 10,000 MSM, HIV infection was initially seeded in 10% of the population, urethral NG and CT in 0.15% of the population, rectal NG and CT in 0.15% of the population. A set of burn-in simulations was then used to allow the natural dynamics of HIV and STI transmission, demography, and other population features to evolve over time. The goal of the burn-in simulation was to arrive at a network of MSM that was independent of the initial conditions resulting from the seeding. This also established a population composition with behavioral and biological features calibrated to match external targets for HIV prevalence of 15% from the national estimate of HIV prevalence among MSM, which harmonized MSM population size estimates with publicly available HIV surveillance data.131 This differs from our previous models, which were calibrated to HIV incidence and prevalence obtained from previous network and incidence studies of Atlanta MSM.132,133 We allowed for slight increases in the final year of the burn-in model to account for the recently observed trends of increasing STIs among MSM.

Many STI-specific and HIV/STI models of disease transmission have been parameterized using populations both in the United States and internationally. These models have differed in type, including deterministic compartmental models, stochastic models, and agent-based transmission models. They have also differed by the populations explicitly modeled, whether MSM only, heterosexual men and women only, or a combination of both populations. Given the variation in parameter values from population to population, we use and evaluate information and estimates from models of male-to-female (MTF), female-to-male (FTM), and male-to-male disease transmission to establish our parameters and prior distributions. These include calibrated estimates from published mathematical models, findings from natural history studies that have been parameters in those models, and estimates where other information is not available.

Table S2 summarizes the primary STI-related parameters from these models. We used approximate Bayesian computation to define model parameters with uncertain values, construct prior distributions for those parameters, and fit the model to HIV/STI prevalence and incidence data to estimate the posterior distributions of those parameter values. In Table S2, we provide the posterior values of those parameters, prior distributions (all uniform over the ranges shown), and key references consulted in forming the shape of the priors. Parameter values with a N/A value for the prior were not calibrated and assumed fixed as the posterior mean value shown in the table.

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| **Table S2.** Parameters, Posterior Value, Prior Distributions, and Sources for STI-related Model Parameters |
| **Parameter** | **Value** | **Priors** | **Source** |
| **STI Screening and Epidemic Parameters** |  |  |  |
| *Per-act acquisition probability* |   |   |   |
| Rectal Gonorrhea | 0.5364 | 0.30 – 0.60 | 53,63,93 |
| Urethral Gonorrhea | 0.4347 | 0.10 – 0.50 | 53,63,93 |
| Rectal Chlamydia | 0.2494 | 0.30 – 0.60 | 39,93,134 |
| Urethral Chlamydia | 0.1944 | 0.10 – 0.50 | 9,93,96 |
| *Probability of symptomatic infection* |   |   |   |
| Rectal Gonorrhea | 0.1600 | N/A | 71 |
| Urethral Gonorrhea | 0.8000 | N/A | 71 (reduced by 0.10 to account for STD clinic population) |
| Rectal Chlamydia | 0.1400 | N/A | 71 |
| Urethral Chlamydia | 0.4800 | N/A | 71 (reduced by 0.10 to account for STD clinic population) |
| *Duration of untreated infection*  |   |   |   |
| Gonorrhea (days) | 175.0000 | N/A | 5,48,71 |
| Chlamydia (days) | 310.0000 | N/A | 5,54,57 |
| *HIV acquisition risk ratio multiplier* |   |   |   |
| Rectal STI Infection | 2.1759 | 1.50 – 3.00 | 36,37 |
| Urethral STI Infection | 1.5648 | 1.00 – 2.50 | 38 |
| *STI transmission multipliers* |   |   |   |
| Condom use | 0.3000 | N/A | 73,74 |
| *Probability of treatment given symptoms* |   |   |   |
| Gonorrhea | 0.9000 | --- | 71,95,96 |
| Chlamydia | 0.8500 | --- | 71,95,96 |
| *Duration of complete recovery (days)* |   |   |   |
| Gonorrhea | 7.0000 | N/A | Assumption |
| Chlamydia | 7.0000 | N/A | Assumption |
| **EPT Parameters** |  |  |  |
| *EPT Risk Interval (days)* | 60.00 | N/A | 104,135 |
| *EPT Coverage (Provision to Treated Index Partner)* | 0.20 | N/A | 109,110,114,115 |
| *Likelihood of EPT Provision to Non-Index Partner* |  |  | 109,114,117–120,122,124 |
|  Existing Main Partnership | 0.50  | N/A | Assumption |
|  Former Main Partnership | 0.40 | N/A | Assumption |
|  Existing Casual Partnership | 0.40 | N/A | Assumption |
|  Former Casual Partnership | 0.30 | N/A | Assumption |
|  One-Off Partnership | 0.20 | N/A | Assumption |
| *Likelihood of EPT Uptake by Non-Index Partner* |  |  | 97,109,111,113,119,120,123–125 |
|  Main Partnership | 0.80 | N/A | Assumption |
|  Casual Partnership | 0.80 | N/A | Assumption |
|  One-Off Partnership | 0.80 | N/A | Assumption |
| *Treatment Success After EPT Uptake* |  |  |  |
|  *Neisseria gonorrhoeae* (NG) | 1.0 | N/A | Assumption |
|  *Chlamydia trachomatis* (CT) | 1.0 | N/A | Assumption |
| EPT Data Sources: 97,104,116–125,108,126–130,135–139,109,140–149,110,150–158,111–115 |

The targeted NG and CT incidence rates were based on results from non-PrEP using cohorts in a recent meta-analysis159 which included data from two Atlanta-based cohorts.132,133 NG incidence rates were complemented by an estimate of incidence among MSM attending STD clinics that were part of the STD Surveillance Network (SSuN).160 An HIV prevalence target of 15% was extracted from a published analysis of rates of prevalent infection which combined MSM population size estimates with public HIV surveillance data.131

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| Table S3: Epidemiological targets for calibration |
| Statistic | Gonorrhea incidence | Chlamydia incidence | HIV prevalence |
| Target | 4.2 cases / 100 person-years | 6.6 cases/ 100 person-years | 15% |
| Source | 159 | 159 | 131 |

We used approximate Bayesian computation with sequential Monte Carlo sampling (ABC-SMC) methods32,161 to calibrate behavioral parameters in which there was measurement uncertainty in order to match the simulated HIV prevalence and STI incidence at the end of the burn-in simulations to the targeted HIV prevalence and STI incidence. The details of ABC depend on the specific algorithm used, but in this case, ABC-SMC proceeded as follows.

For each candidate parameter, $θ$, to be estimated, we:

1. Sampled a candidate $θ^{i}$ from a prior distribution $π(θ)$
2. Simulated the epidemic model with candidate value, $θ^{i}$.
3. Tested if a distance statistic, $d$ (e.g., the difference between observed HIV prevalence and model simulated prevalence) was greater than a tolerance threshold, $ϵ$.
	1. If $d> ϵ$ then discard
	2. If $d< ϵ$ then add the candidate $θ^{i}$ to the posterior distribution of $θ$.
4. Sample the next sequential candidate, $θ^{i+1}$, either independently from $π(θ)$ (if 3a) or from $θ^{i}$ plus a perturbation kernel with a weight based on the current posterior distribution (if 3b).

For the ABC algorithms to calibrate to the observed HIV prevalence and STI incidence, a total of 500 simulations were required for 100 years of calendar time each. The posterior distributions for the calibrated parameters are listed in Table S2. The target statistics were matched during this burn-in model and also during the baseline background screening base featured in the main manuscript, which featured 44% of sexually active HIV-negative MSM testing regularly on an annual basis for gonorrhea and chlamydia, respectively, and 61% of sexually active HIV-positive MSM testing regularly on an annual basis for gonorrhea and chlamydia, respectively.105

## 13.2 Model Simulations

The intervention scenarios are described fully within the main paper and in the table below (Table S4). Model scenarios and results are compared to the reference (no EPT) model in which only CDC-recommended annual STI screening occurred. For each scenario, we simulated the model scenario 256 times for 10 calendar years each. Data from each simulation were merged, and a complete 256 -simulation data file was retained for each scenario. All burn-in and intervention simulations were conducted on the Hyak high-performance computing platform at the University of Washington.

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| Table S4: Modeled Scenarios |
| **Analysis** | **Details** |
| Reference case | STI Screening Coverage:* Coverage of HIV+: 61% of sexually active MSM screened for NG and CT
* Coverage of HIV-: 44% of sexually active MSM screened for NG and CT
* Frequency of screening: Annual

Expedited Partner Therapy* Coverage: 0%
* Partnership Window: 2 months
* Provision to Partners:
	+ Main, ongoing: 50%
	+ Main, ended: 40%
	+ Casual, ongoing: 40%
	+ Casual, ended: 30%
	+ One-Time: 20%
* Uptake by Partners:
	+ Main: 80%
	+ Casual: 80%
	+ One-Time: 80%
* Successful EPT Treatment: 100%
 |
| EPT Coverage for Index Patients (Provider 🡪 Patient) | STI Screening Coverage:* Coverage of HIV+: 61% of sexually active MSM screened for NG and CT
* Coverage of HIV-: 44% of sexually active MSM screened for NG and CT
* Frequency of screening: Annual

Expedited Partner Therapy* *Coverage: 10% - 100% (varying)*
* Partnership Window: 2 months
* Provision to Partners:
	+ Main, ongoing: 50%
	+ Main, ended: 40%
	+ Casual, ongoing: 40%
	+ Casual, ended: 30%
	+ One-Time: 20%
* Uptake by Partners:
	+ Main: 80%
	+ Casual: 80%
	+ One-Time: 80%
* Successful EPT Treatment: 100%
 |
| Varying EPT Partnership Windows | STI Screening Coverage:* Coverage of HIV+: 61% of sexually active MSM screened for NG and CT
* Coverage of HIV-: 44% of sexually active MSM screened for NG and CT
* Frequency of screening: Annual

Expedited Partner Therapy* Coverage: 20%
* *Partnership Window: 1-6 months*
* Provision to Partners:
	+ Main, ongoing: 50%
	+ Main, ended: 40%
	+ Casual, ongoing: 40%
	+ Casual, ended: 30%
	+ One-Time: 20%
* Uptake by Partners:
	+ Main: 80%
	+ Casual: 80%
	+ One-Time: 80%
* Successful EPT Treatment: 100%
 |
| Varying Provision of EPT to Partners | STI Screening Coverage:* Coverage of HIV+: 61% of sexually active MSM screened for NG and CT
* Coverage of HIV-: 44% of sexually active MSM screened for NG and CT
* Frequency of screening: Annual

Expedited Partner Therapy* Coverage: 20%
* Partnership Window: 2 months
* *Provision to Partners:*
	+ *Main, ongoing: Increase of 10-50%*
	+ *Main, Increase of 10-50%*
	+ *Casual, ongoing: Increase of 10-50%*
	+ *Casual, ended: Increase of 10-50%*
	+ *One-Time: Increase of 10-50%*
* Uptake by Partners:
	+ Main: 80%
	+ Casual: 80%
	+ One-Time: 80%
* Successful EPT Treatment: 100%
 |
| Varying Uptake of EPT by Partners | STI Screening Coverage:* Coverage of HIV+: 61% of sexually active MSM screened for NG and CT
* Coverage of HIV-: 44% of sexually active MSM screened for NG and CT
* Frequency of screening: Annual

Expedited Partner Therapy* Coverage: 20%
* Partnership Window: 2 months
* Provision to Partners:
	+ Main, ongoing: 50%
	+ Main, ended: 40%
	+ Casual, ongoing: 40%
	+ Casual, ended: 30%
	+ One-Time: 20%
* Uptake by Partners:
	+ *Main: Increase of 10-20%*
	+ *Casual: Increase of 10-20%*
	+ *One-Time: 80%*
* Successful EPT Treatment: 100%
 |

# SUPPLEMENTAL RESULTS

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| **Supplementary Table 5.** Expedited Partner Therapy (EPT) Doses Given to Index Patients, Received by Partners, and Taken by Partners, and the Percent of Partners Provided with EPT Medication Who Have a Prevalent HIV Infection Across EPT Continuum Steps among Men Who Have Sex with Men |
|  | **EPT Doses Given to Index***(Median, IQR)* | **EPT Doses Received by Partners** *(Median, IQR)* | **EPT Doses Taken by Partners** *(Median, IQR)* | **Percent of Partners Provided With HIV** *(Median, IQR)* |
| **Reference Model** | -- | --- | --- | --- |
| **EPT Coverage (Provision to Index)** |   |   |   |   |
| 10% | 843 (744, 951) | 600 (530, 694) | 479 (427, 556) | 17.90 (16.70, 19.13) |
| 20% | 1482 (1316, 1685) | 1016 (892, 1162) | 820 (716, 927) | 17.56 (16.43, 18.61) |
| 30% | 1976 (1733, 2229) | 1294 (1152, 1458) | 1039 (919, 1174) | 17.79 (16.82, 18.64) |
| 40% | 2350 (2094, 2645) | 1494 (1330, 1664) | 1192 (1067, 1335) | 17.74 (16.76, 18.64) |
| 50% | 2822 (2483, 3134) | 1724 (1527, 1914) | 1382 (1226, 1526) | 17.71 (16.74, 18.58) |
| 60% | 3153 (2816, 3505) | 1872 (1670, 2058) | 1500 (1337, 1640) | 17.75 (16.72, 18.56) |
| 70% | 3403 (2983, 3888) | 1972 (1747, 2235) | 1579 (1398, 1789) | 17.75 (16.89, 18.57) |
| 80% | 3750 (3267, 4337) | 2116 (1827, 2394) | 1674 (1457, 1912) | 17.75 (16.74, 18.62) |
| 90% | 4004 (3561, 4496) | 2180 (1975, 2430) | 1755 (1582, 1934) | 17.76 (16.77, 18.50) |
| 100% | 4305 (3918, 4959) | 2304 (2108, 2609) | 1836 (1678, 2087) | 17.61 (16.68, 18.38) |
| **EPT Partnership Window (20% Coverage)** |   |   |   |   |
| 1 month (28 days) | 1488 (1312, 1692) | 878 (774, 1009) | 702 (620, 810) | 17.52 (16.59, 18.61) |
| 3 months (91 days) | 1438 (1265, 1636) | 1090 (944, 1235) | 872 (762, 985) | 17.94 (16.89, 19.03) |
| 4 months (119 days) | 1467 (1293, 1650) | 1202 (1050, 1352) | 956 (851, 1086) | 17.65 (16.74, 18.72) |
| 5 months (154 days) | 1464 (1301, 1644) | 1316 (1171, 1453) | 1045 (930, 1166) | 18.02 (17.03, 18.83) |
| 6 months (182 days) | 1492 (1316, 1637) | 1428 (1272, 1561) | 1146 (1016, 1249) | 17.95 (17.11, 18.64) |
| **EPT Provision to Non-Index Partner (20% Coverage)** |   |   |   |   |
| Base + 10% | 1433 (1263, 1642) | 1090 (951, 1238) | 872 (762, 1000) | 17.64 (16.70, 18.67) |
| Base + 20% | 1396 (1222, 1544) | 1146 (1004, 1265) | 915 (802, 1026) | 17.67 (16.61, 18.74) |
| Base + 30% | 1354 (1199, 1512) | 1215 (1077, 1381) | 972 (863, 1102) | 17.84 (16.75, 18.93) |
| Base + 40% | 1304 (1173, 1454) | 1256 (1121, 1411) | 1008 (895, 1132) | 17.69 (16.77, 18.62) |
| Base + 50% | 1252 (1116, 1402) | 1308 (1154, 1465) | 1044 (929, 1172) | 17.57 (16.67, 18.70) |
| **EPT Uptake by Non-Index Partner (20% Coverage)** |   |   |   |   |
| Base + 10% | 1445 (1263, 1628) | 978 (868, 1123) | 860 (768, 983) | 17.69 (16.76, 18.80) |
| Base + 20% | 1382 (1232, 1536) | 951 (839, 1054) | 912 (808, 1015) | 17.69 (16.54, 18.88) |
| IQR: interquartile range (25% and 75% percentiles) of the simulation outcomes; Incidence expressed per 100 person-years at risk at final year of simulation; All outcomes are compared to the reference model. |

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| **Supplementary Table 6.** Gonorrhea (NG) Incidence, Percent of Infections Averted (PIA), Expedited Partner Therapy (EPT) Doses Taken by Partners, and Per-Capita Number of Times Infected Across EPT Provision (Distribution to Partner) Levels, Limited by Partnership Type, among Men Who Have Sex with Men |
|  | **Incidence** *(Median, IQR)* | **Cumulative PIA** *(Median, IQR)* | **Total EPT Doses****Taken** *(Median, IQR)* | **Per-Capita Times Infected** *(Median, IQR)* |
| **Reference Model** | 4.64 (2.66, 6.95) | --- | --- | 0.47 (0.34, 0.59) |
| **EPT Coverage (Provision to Index)** |   |   |   |   |
| 10% | 2.45 (1.08, 3.87) | 0.25 (-0.09, 0.49) | 201 (156, 270) | 0.34 (0.26, 0.46) |
| 20% | 1.56 (0.64, 3.01) | 0.41 (0.03, 0.59) | 324 (236, 411) | 0.29 (0.21, 0.38) |
| 30% | 1.08 (0.33, 2.07) | 0.46 (0.22, 0.63) | 386 (284, 507) | 0.25 (0.18, 0.33) |
| 40% | 0.70 (0.21, 1.47) | 0.54 (0.37, 0.67) | 430 (319, 548) | 0.21 (0.16, 0.28) |
| 50% | 0.60 (0.17, 1.30) | 0.58 (0.37, 0.71) | 482 (346, 613) | 0.20 (0.14, 0.26) |
| 60% | 0.52 (0.13, 1.10) | 0.60 (0.37, 0.71) | 521 (421, 642) | 0.19 (0.15, 0.24) |
| 70% | 0.37 (0.01, 1.02) | 0.62 (0.42, 0.76) | 532 (402, 710) | 0.17 (0.13, 0.23) |
| 80% | 0.37 (0.00, 0.94) | 0.64 (0.45, 0.75) | 598 (430, 742) | 0.18 (0.13, 0.23) |
| 90% | 0.22 (0.00, 0.76) | 0.68 (0.48, 0.76) | 564 (434, 751) | 0.16 (0.12, 0.21) |
| 100% | 0.24 (0.00, 0.86) | 0.66 (0.47, 0.76) | 641 (470, 816) | 0.16 (0.12, 0.21) |
| **EPT Partnership Window (20% Coverage)** |   |   |   |   |
| 1 month (28 days) | 1.78 (0.72, 3.02) | 0.35 (0.10, 0.57) | 274 (216, 365) | 0.29 (0.23, 0.38) |
| 3 months (91 days) | 1.55 (0.54, 2.62) | 0.42 (0.15, 0.61) | 328 (242, 428) | 0.27 (0.20, 0.36) |
| 4 months (119 days) | 1.42 (0.62, 2.70) | 0.42 (0.12, 0.59) | 354 (274, 488) | 0.27 (0.21, 0.37) |
| 5 months (154 days) | 1.58 (0.70, 2.83) | 0.40 (0.12, 0.59) | 396 (306, 505) | 0.28 (0.22, 0.35) |
| 6 months (182 days) | 1.59 (0.64, 2.84) | 0.36 (0.02, 0.58) | 445 (334, 570) | 0.29 (0.22, 0.38) |
| **EPT Provision to Non-Index Partner (20% Coverage)** |   |   |   |   |
| Base + 10% | 1.59 (0.62, 2.76) | 0.42 (0.17, 0.60) | 338 (252, 434) | 0.28 (0.20, 0.36) |
| Base + 20% | 1.29 (0.49, 2.42) | 0.45 (0.16, 0.62) | 352 (266, 458) | 0.27 (0.19, 0.35) |
| Base + 30% | 1.23 (0.46, 2.28) | 0.45 (0.17, 0.64) | 383 (273, 483) | 0.26 (0.19, 0.33) |
| Base + 40% | 1.08 (0.29, 1.94) | 0.53 (0.24, 0.67) | 368 (280, 488) | 0.23 (0.18, 0.31) |
| Base + 50% | 0.94 (0.30, 1.49) | 0.51 (0.27, 0.66) | 386 (301, 494) | 0.23 (0.18, 0.29) |
| **EPT Uptake by Non-Index Partner (20% Coverage)** |   |   |   |   |
| Base + 10% | 1.61 (0.66, 2.45) | 0.39 (0.13, 0.58) | 338 (261, 430) | 0.28 (0.21, 0.36) |
| Base + 20% | 1.20 (0.51, 2.22) | 0.45 (0.20, 0.62) | 346 (258, 429) | 0.26 (0.20, 0.33) |
| IQR: interquartile range (25% and 75% percentiles) of the simulation outcomes; Incidence expressed per 100 person-years at risk at final year of simulation; All outcomes are compared to the reference model. |

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| **Supplementary Table 7.** Chlamydia (CT) Incidence, Percent of Infections Averted (PIA), Expedited Partner Therapy (EPT) Doses Taken by Partners, and Per-Capita Number of Times Infected Across EPT Provision (Distribution to Partner) Levels, Limited by Partnership Type, among Men Who Have Sex with Men |
|  | **Incidence** *(Median, IQR)* | **Cumulative PIA** *(Median, IQR)* | **Total EPT Doses Taken** *(Median, IQR)* | **Per-Capita Times Infected** *(Median, IQR)* |
| **Reference Model** | 6.85 (5.94, 7.85) | --- | --- | 0.72 (0.65, 0.79) |
| **EPT Coverage (Provision to Index)** |   |   |   |   |
| 10% | 5.23 (4.27, 6.17) | 0.13 (0.01, 0.23) | 274 (252, 304) | 0.62 (0.57, 0.69) |
| 20% | 4.34 (3.49, 5.06) | 0.20 (0.08, 0.30) | 486 (433, 539) | 0.58 (0.53, 0.64) |
| 30% | 3.68 (3.00, 4.43) | 0.28 (0.16, 0.38) | 644 (574, 703) | 0.53 (0.47, 0.58) |
| 40% | 3.07 (2.37, 3.85) | 0.33 (0.25, 0.42) | 764 (693, 842) | 0.49 (0.44, 0.54) |
| 50% | 2.76 (1.95, 3.45) | 0.36 (0.27, 0.45) | 894 (795, 988) | 0.47 (0.42, 0.52) |
| 60% | 2.37 (1.82, 2.97) | 0.42 (0.31, 0.50) | 968 (871, 1066) | 0.44 (0.39, 0.49) |
| 70% | 2.06 (1.56, 2.65) | 0.46 (0.36, 0.52) | 1018 (924, 1138) | 0.41 (0.37, 0.45) |
| 80% | 1.85 (1.34, 2.35) | 0.48 (0.39, 0.54) | 1080 (971, 1199) | 0.39 (0.35, 0.44) |
| 90% | 1.73 (1.20, 2.19) | 0.49 (0.41, 0.56) | 1150 (1047, 1269) | 0.38 (0.34, 0.42) |
| 100% | 1.48 (1.13, 1.96) | 0.50 (0.44, 0.58) | 1215 (1105, 1337) | 0.37 (0.34, 0.41) |
| **EPT Partnership Window (20% Coverage)** |   |   |   |   |
| 1 month (28 days) | 4.44 (3.40, 5.33) | 0.20 (0.08, 0.33) | 426 (370, 467) | 0.58 (0.52, 0.64) |
| 3 months (91 days) | 4.36 (3.67, 5.24) | 0.20 (0.08, 0.32) | 536 (476, 594) | 0.58 (0.52, 0.64) |
| 4 months (119 days) | 4.41 (3.62, 5.29) | 0.20 (0.09, 0.30) | 582 (532, 638) | 0.58 (0.53, 0.64) |
| 5 months (154 days) | 4.18 (3.44, 5.07) | 0.21 (0.08, 0.33) | 642 (576, 701) | 0.57 (0.52, 0.63) |
| 6 months (182 days) | 4.30 (3.52, 4.98) | 0.22 (0.11, 0.32) | 681 (620, 750) | 0.57 (0.52, 0.63) |
| **EPT Provision to Non-Index Partner (20% Coverage)** |   |   |   |   |
| Base + 10% | 4.23 (3.42, 5.17) | 0.20 (0.11, 0.32) | 523 (475, 584) | 0.57 (0.51, 0.63) |
| Base + 20% | 4.04 (3.29, 4.93) | 0.23 (0.13, 0.35) | 561 (499, 611) | 0.55 (0.50, 0.61) |
| Base + 30% | 3.79 (3.03, 4.54) | 0.26 (0.15, 0.36) | 592 (540, 650) | 0.54 (0.49, 0.6) |
| Base + 40% | 3.59 (2.93, 4.30) | 0.27 (0.15, 0.37) | 627 (565, 698) | 0.53 (0.49, 0.59) |
| Base + 50% | 3.38 (2.51, 4.21) | 0.29 (0.19, 0.40) | 653 (574, 719) | 0.51 (0.46, 0.57) |
| **EPT Uptake by Non-Index Partner (20% Coverage)** |   |   |   |   |
| Base + 10% | 4.00 (3.28, 5.06) | 0.22 (0.09, 0.34) | 520 (468, 580) | 0.56 (0.51, 0.63) |
| Base + 20% | 4.06 (3.35, 4.96) | 0.24 (0.14, 0.32) | 566 (509, 620) | 0.56 (0.51, 0.61) |
| IQR: interquartile range (25% and 75% percentiles) of the simulation outcomes; Incidence expressed per 100 person-years at risk at final year of simulation; All outcomes are compared to the reference model. |

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| **Supplementary Table 8.** Combined Gonorrhea and Chlamydia (NG/CT) Partners Eligible for Expedited Partner Therapy (EPT), Partners Eligible Per-Time Step, Total EPT Doses Provided to Index Patients, Total Doses Provided from Index Patients to Partners, and Proportion of Partners Provided with EPT Medication by Partnership Type by Coverage, Partnership Window Interval, Provision to Non-Index Partner, Uptake by Non-Index Partner of EPT Medication among Men Who Have Sex with Men in the United States |
|  | **Total Partners Eligible** *(Median, IQR)* | **Total Partners Eligible Per-Time Step** *(Median, IQR)* | **Total EPT Doses Provided to Index** *(Median, IQR)* | **Total EPT Doses Provided to Partners** *(Median, IQR)* | **Proportion of Main Partners Provided Per Time Step** *(Median, IQR)* | **Proportion of Casual Partners Provided Per Time Step** *(Median, IQR)* | **Proportion of One-Time Partners Provided Per Time Step** *(Median, IQR)* |
| **Reference Model** | --- | --- | --- |   | --- | --- | --- |
| **EPT Coverage (Provision to Index)** |  |  |   |   |   |   |   |
| 10% | 1779 (1575, 2053) | 3.42 (3.03, 3.95) | 843 (744, 951) | 600 (530, 694) | 0.49 (0.47, 0.51) | 0.38 (0.37, 0.40) | 0.20 (0.19, 0.21) |
| 20% | 3036 (2666, 3425) | 5.84 (5.13, 6.59) | 1482 (1316, 1685) | 1016 (892, 1162) | 0.49 (0.47, 0.51) | 0.38 (0.37, 0.39) | 0.20 (0.19, 0.21) |
| 30% | 3867 (3404, 4374) | 7.44 (6.55, 8.41) | 1976 (1733, 2229) | 1294 (1152, 1458) | 0.49 (0.47, 0.50) | 0.38 (0.38, 0.39) | 0.20 (0.19, 0.21) |
| 40% | 4437 (3973, 4990) | 8.53 (7.64, 9.60) | 2350 (2094, 2645) | 1494 (1330, 1664) | 0.49 (0.47, 0.50) | 0.38 (0.38, 0.39) | 0.20 (0.19, 0.21) |
| 50% | 5163 (4560, 5744) | 9.93 (8.77, 11.05) | 2822 (2483, 3134) | 1724 (1527, 1914) | 0.49 (0.48, 0.50) | 0.38 (0.37, 0.39) | 0.20 (0.19, 0.21) |
| 60% | 5592 (5031, 6167) | 10.75 (9.67, 11.86) | 3153 (2816, 3505) | 1872 (1670, 2058) | 0.49 (0.47, 0.50) | 0.38 (0.37, 0.39) | 0.20 (0.19, 0.21) |
| 70% | 5902 (5174, 6697) | 11.35 (9.95, 12.88) | 3403 (2983, 3888) | 1972 (1747, 2235) | 0.49 (0.47, 0.50) | 0.38 (0.37, 0.39) | 0.20 (0.19, 0.21) |
| 80% | 6321 (5515, 7186) | 12.16 (10.61, 13.82) | 3750 (3267, 4337) | 2116 (1827, 2394) | 0.48 (0.47, 0.50) | 0.38 (0.37, 0.39) | 0.20 (0.19, 0.21) |
| 90% | 6521 (5911, 7282) | 12.54 (11.37, 14.00) | 4004 (3561, 4496) | 2180 (1975, 2430) | 0.49 (0.48, 0.50) | 0.38 (0.38, 0.39) | 0.20 (0.19, 0.21) |
| 100% | 6894 (6359, 7794) | 13.26 (12.23, 14.99) | 4305 (3918, 4959) | 2304 (2108, 2609) | 0.48 (0.47, 0.50) | 0.38 (0.37, 0.39) | 0.20 (0.19, 0.21) |
| **EPT Partnership Window (20% Coverage)** |  |  |   |   |   |   |   |
| 1 month (28 days) | 2464 (2174, 2804) | 4.74 (4.18, 5.39) | 1488 (1312, 1692) | 878 (774, 1009) | 0.50 (0.48, 0.51) | 0.39 (0.38, 0.40) | 0.20 (0.19, 0.21) |
| 3 months (91 days) | 3340 (2943, 3811) | 6.42 (5.66, 7.33) | 1438 (1265, 1636) | 1090 (944, 1235) | 0.49 (0.46, 0.50) | 0.38 (0.37, 0.39) | 0.20 (0.19, 0.21) |
| 4 months (119 days) | 3821 (3357, 4330) | 7.35 (6.46, 8.33) | 1467 (1293, 1650) | 1202 (1050, 1352) | 0.48 (0.46, 0.49) | 0.37 (0.36, 0.38) | 0.20 (0.19, 0.21) |
| 5 months (154 days) | 4312 (3856, 4779) | 8.29 (7.42, 9.19) | 1464 (1301, 1644) | 1316 (1171, 1453) | 0.47 (0.46, 0.49) | 0.37 (0.36, 0.37) | 0.20 (0.19, 0.21) |
| 6 months (182 days) | 4736 (4219, 5232) | 9.11 (8.11, 10.06) | 1492 (1316, 1637) | 1428 (1272, 1561) | 0.47 (0.46, 0.49) | 0.36 (0.35, 0.37) | 0.20 (0.19, 0.21) |
| **EPT Provision to Non-Index Partner** |  |  |   |   |   |   |   |
| Base + 10% | 2919 (2593, 3343) | 5.61 (4.99, 6.43) | 1433 (1263, 1642) | 1090 (951, 1238) | 0.54 (0.52, 0.55) | 0.42 (0.41, 0.43) | 0.22 (0.21, 0.23) |
| Base + 20% | 2836 (2480, 3148) | 5.45 (4.77, 6.05) | 1396 (1222, 1544) | 1146 (1004, 1265) | 0.58 (0.57, 0.60) | 0.46 (0.45, 0.47) | 0.24 (0.23, 0.25) |
| Base + 30% | 2792 (2441, 3138) | 5.37 (4.69, 6.04) | 1354 (1199, 1512) | 1215 (1077, 1381) | 0.63 (0.62, 0.65) | 0.50 (0.49, 0.51) | 0.26 (0.25, 0.27) |
| Base + 40% | 2660 (2389, 2981) | 5.11 (4.59, 5.73) | 1304 (1173, 1454) | 1256 (1121, 1411) | 0.68 (0.67, 0.70) | 0.53 (0.52, 0.55) | 0.28 (0.27, 0.29) |
| Base + 50% | 2589 (2297, 2905) | 4.98 (4.42, 5.59) | 1252 (1116, 1402) | 1308 (1154, 1465) | 0.73 (0.72, 0.74) | 0.57 (0.56, 0.58) | 0.3 (0.29, 0.31) |
| **EPT Uptake by Non-Index Partner** |  |  |   |   |   |   |   |
| Base + 10% | 2930 (2596, 3322) | 5.63 (4.99, 6.39) | 1445 (1263, 1628) | 978 (868, 1123) | 0.49 (0.47, 0.50) | 0.38 (0.37, 0.39) | 0.20 (0.19, 0.21) |
| Base + 20% | 2826 (2491, 3159) | 5.43 (4.79, 6.08) | 1382 (1232, 1536) | 951 (839, 1054) | 0.49 (0.47, 0.51) | 0.38 (0.37, 0.39) | 0.20 (0.19, 0.21) |
| IQR: interquartile range (25% and 75% percentiles) of the simulation outcomes; Incidence expressed per 100 person-years at risk at final year of simulation; All outcomes are compared to the reference model.  |

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| **Supplementary Table 9.** Gonorrhea (NG) Incidence, Percent of Infections Averted (PIA), Expedited Partner Therapy (EPT) Doses Taken by Partners, and Per-Capita Number of Times Infected Across EPT Coverage (Provision to Index) Levels, Limited by Partnership Type, among Men Who Have Sex with Men |
|  | **Incidence** *(Median, IQR)* | **Cumulative PIA** *(Median, IQR)* | **Total EPT Doses****Taken** *(Median, IQR)* | **Per-Capita Times Infected** *(Median, IQR)* |
| **Base Model** | 4.64 (2.66, 6.95) | --- | --- | 0.47 (0.34, 0.59) |
| **Coverage for Index Patients (Provision to Main Partners Only)\*** |  |  |  |  |
| 10% | 4.01 (2.32, 5.90) | 0.07 (-0.34, 0.39) | 53 (39, 66) | 0.44 (0.32, 0.55) |
| 20% | 3.41 (1.97, 5.66) | 0.12 (-0.31, 0.42) | 90 (70, 116) | 0.40 (0.29, 0.52) |
| 30% | 3.18 (1.67, 4.77) | 0.20 (-0.27, 0.46) | 122 (87, 158) | 0.40 (0.28, 0.51) |
| 40% | 2.96 (1.73, 4.45) | 0.21 (-0.12, 0.44) | 143 (116, 182) | 0.38 (0.29, 0.48) |
| 50% | 2.90 (1.64, 4.51) | 0.22 (-0.22, 0.48) | 172 (124, 221) | 0.37 (0.27, 0.48) |
| 60% | 2.90 (1.63, 4.40) | 0.16 (-0.15, 0.50) | 190 (148, 248) | 0.36 (0.28, 0.47) |
| 70% | 2.47 (1.02, 3.93) | 0.29 (-0.08, 0.50) | 190 (140, 259) | 0.33 (0.24, 0.45) |
| 80% | 2.69 (1.35, 4.40) | 0.25 (-0.13, 0.54) | 224 (163, 294) | 0.35 (0.25, 0.45) |
| 90% | 2.55 (1.24, 3.98) | 0.30 (-0.03, 0.51) | 227 (174, 296) | 0.33 (0.26, 0.43) |
| 100% | 2.58 (1.32, 3.96) | 0.25 (-0.04, 0.47) | 256 (193, 319) | 0.35 (0.25, 0.45) |
| **Coverage for Index Patients (Provision to Casual Partners Only)\*** |  |  |  |  |
| 10% | 3.10 (1.78, 4.84) | 0.13 (-0.25, 0.49) | 135 (97, 169) | 0.38 (0.27, 0.50) |
| 20% | 2.25 (1.20, 3.85) | 0.23 (-0.03, 0.48) | 222 (165, 283) | 0.34 (0.26, 0.45) |
| 30% | 1.89 (0.88, 3.24) | 0.33 (0.05, 0.55) | 281 (204, 369) | 0.31 (0.23, 0.42) |
| 40% | 1.52 (0.69, 2.75) | 0.41 (0.15, 0.58) | 310 (253, 402) | 0.27 (0.22, 0.36) |
| 50% | 1.61 (0.69, 2.54) | 0.39 (0.14, 0.58) | 385 (280, 500) | 0.28 (0.21, 0.38) |
| 60% | 1.05 (0.42, 2.16) | 0.44 (0.26, 0.62) | 400 (301, 508) | 0.26 (0.19, 0.32) |
| 70% | 1.11 (0.41, 2.08) | 0.47 (0.20, 0.63) | 432 (326, 542) | 0.25 (0.19, 0.32) |
| 80% | 0.94 (0.26, 1.65) | 0.51 (0.29, 0.67) | 434 (326, 546) | 0.23 (0.17, 0.28) |
| 90% | 1.13 (0.41, 1.90) | 0.49 (0.26, 0.66) | 482 (358, 626) | 0.24 (0.18, 0.31) |
| 100% | 0.97 (0.38, 1.82) | 0.51 (0.28, 0.66) | 504 (391, 648) | 0.23 (0.18, 0.30) |
| **Coverage for Index Patients (Provision to One-Time Partners Only)\*** |  |  |  |  |
| 10% | 4.05 (2.28, 6.36) | 0.11 (-0.34, 0.36) | 52 (36, 67) | 0.43 (0.31, 0.56) |
| 20% | 4.05 (2.58, 6.12) | 0.06 (-0.41, 0.33) | 99 (76, 130) | 0.45 (0.33, 0.57) |
| 30% | 3.98 (2.52, 5.61) | 0.10 (-0.33, 0.36) | 130 (104, 164) | 0.42 (0.33, 0.51) |
| 40% | 4.08 (2.45, 6.13) | 0.05 (-0.40, 0.35) | 174 (134, 221) | 0.43 (0.33, 0.56) |
| 50% | 4.12 (2.21, 5.81) | 0.05 (-0.26, 0.34) | 212 (162, 264) | 0.45 (0.33, 0.55) |
| 60% | 3.82 (2.00, 5.69) | 0.10 (-0.37, 0.36) | 234 (178, 301) | 0.42 (0.32, 0.54) |
| 70% | 4.29 (2.42, 5.80) | 0.04 (-0.30, 0.38) | 269 (201, 337) | 0.45 (0.33, 0.55) |
| 80% | 4.06 (2.28, 5.48) | 0.14 (-0.27, 0.41) | 280 (216, 345) | 0.41 (0.31, 0.52) |
| 90% | 3.66 (1.99, 5.61) | 0.10 (-0.25, 0.38) | 296 (227, 388) | 0.40 (0.31, 0.53) |
| 100% | 3.53 (2.02, 5.56) | 0.10 (-0.25, 0.37) | 310 (243, 410) | 0.40 (0.31, 0.53) |
| IQR: interquartile range (25% and 75% percentiles) of the simulation outcomes; Incidence expressed per 100 person-years at risk at final year of simulation; All outcomes are compared to the reference model.\* 0% Provision to Other Partnership Types |

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| **Supplementary Table 10.** Chlamydia (CT) Incidence, Percent of Infections Averted (PIA), Expedited Partner Therapy (EPT) Doses Taken by Partners, and Per-Capita Number of Times Infected Across EPT Coverage (Provision to Index) Levels, Limited by Partnership Type, among Men Who Have Sex with Men |
|  | **Incidence** *(Median, IQR)* | **Cumulative PIA** *(Median, IQR)* | **Total EPT Doses****Taken** *(Median, IQR)* | **Per-Capita Times Infected** *(Median, IQR)* |
| **Base Model** | 6.85 (5.94, 7.85) | --- | --- | 0.72 (0.65, 0.79) |
| **Coverage for Index Patients (Provision to Main Partners Only)\*** |  |  |  |  |
| 10% | 6.22 (5.29, 7.49) | 0.03 (-0.12, 0.16) | 64 (56, 72) | 0.70 (0.63, 0.76) |
| 20% | 6.05 (4.99, 7.22) | 0.07 (-0.06, 0.18) | 117 (104, 130) | 0.68 (0.62, 0.75) |
| 30% | 5.61 (4.50, 6.87) | 0.08 (-0.05, 0.22) | 160 (144, 178) | 0.65 (0.59, 0.73) |
| 40% | 5.46 (4.53, 6.44) | 0.12 (-0.04, 0.23) | 204 (184, 223) | 0.64 (0.59, 0.71) |
| 50% | 5.17 (4.45, 6.12) | 0.14 (0.02, 0.24) | 238 (217, 262) | 0.63 (0.57, 0.69) |
| 60% | 5.21 (4.23, 6.09) | 0.14 (0.00, 0.24) | 276 (250, 303) | 0.62 (0.57, 0.69) |
| 70% | 4.83 (3.95, 5.94) | 0.17 (0.04, 0.27) | 296 (271, 324) | 0.61 (0.55, 0.66) |
| 80% | 4.83 (3.93, 5.79) | 0.18 (0.05, 0.29) | 321 (289, 354) | 0.59 (0.53, 0.66) |
| 90% | 4.79 (3.93, 5.64) | 0.17 (0.08, 0.29) | 350 (318, 384) | 0.59 (0.54, 0.65) |
| 100% | 4.67 (3.96, 5.66) | 0.18 (0.05, 0.29) | 382 (347, 416) | 0.60 (0.54, 0.66) |
| **Coverage for Index Patients (Provision to Casual Partners Only)\*** |  |  |  |  |
| 10% | 5.99 (5.00, 6.96) | 0.07 (-0.06, 0.19) | 174 (155, 186) | 0.67 (0.62, 0.74) |
| 20% | 5.12 (4.14, 6.21) | 0.13 (-0.01, 0.24) | 306 (278, 346) | 0.63 (0.57, 0.69) |
| 30% | 4.60 (3.74, 5.59) | 0.17 (0.05, 0.29) | 424 (370, 465) | 0.60 (0.52, 0.67) |
| 40% | 4.20 (3.26, 4.96) | 0.23 (0.12, 0.34) | 505 (452, 560) | 0.56 (0.50, 0.62) |
| 50% | 3.91 (3.13, 4.71) | 0.24 (0.13, 0.36) | 598 (542, 661) | 0.54 (0.50, 0.61) |
| 60% | 3.57 (2.82, 4.36) | 0.28 (0.16, 0.37) | 668 (604, 740) | 0.53 (0.48, 0.58) |
| 70% | 3.24 (2.64, 3.95) | 0.33 (0.21, 0.41) | 718 (650, 793) | 0.50 (0.45, 0.55) |
| 80% | 3.18 (2.52, 3.85) | 0.32 (0.22, 0.41) | 786 (718, 863) | 0.50 (0.45, 0.55) |
| 90% | 2.98 (2.35, 3.56) | 0.34 (0.22, 0.41) | 850 (779, 916) | 0.49 (0.44, 0.53) |
| 100% | 2.99 (2.21, 3.70) | 0.36 (0.25, 0.45) | 888 (801, 998) | 0.48 (0.42, 0.53) |
| **Coverage for Index Patients (Provision to One-Time Partners Only)\*** |  |  |  |  |
| 10% | 6.62 (5.72, 7.73) | 0.01 (-0.12, 0.13) | 65 (56, 72) | 0.71 (0.65, 0.78) |
| 20% | 6.72 (5.72, 7.80) | 0.03 (-0.11, 0.13) | 121 (109, 135) | 0.72 (0.66, 0.77) |
| 30% | 6.50 (5.45, 7.42) | 0.01 (-0.13, 0.16) | 174 (156, 188) | 0.71 (0.65, 0.77) |
| 40% | 6.35 (5.22, 7.57) | 0.04 (-0.09, 0.15) | 219 (199, 246) | 0.69 (0.63, 0.76) |
| 50% | 6.45 (5.59, 7.46) | 0.00 (-0.11, 0.14) | 272 (248, 292) | 0.72 (0.63, 0.77) |
| 60% | 6.29 (5.23, 7.41) | 0.05 (-0.11, 0.18) | 308 (275, 338) | 0.69 (0.62, 0.76) |
| 70% | 6.19 (5.20, 7.38) | 0.04 (-0.09, 0.16) | 349 (317, 380) | 0.70 (0.62, 0.76) |
| 80% | 6.11 (5.02, 7.06) | 0.08 (-0.07, 0.17) | 374 (347, 416) | 0.67 (0.61, 0.74) |
| 90% | 6.39 (5.32, 7.47) | 0.03 (-0.11, 0.15) | 424 (392, 467) | 0.69 (0.64, 0.77) |
| 100% | 6.31 (5.15, 7.10) | 0.06 (-0.11, 0.16) | 454 (418, 492) | 0.69 (0.62, 0.75) |
| IQR: interquartile range (25% and 75% percentiles) of the simulation outcomes; Incidence expressed per 100 person-years at risk at final year of simulation; All outcomes are compared to the reference model.\* 0% Provision to Other Partnership Types |

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| **Supplementary Table 11.** Gonorrhea (NG) Incidence, Percent of Infections Averted (PIA), Expedited Partner Therapy (EPT) Doses Taken by Partners, and Per-Capita Number of Times Infected Across EPT Provision (Distribution to Partner) Levels, Limited by Partnership Type, among Men Who Have Sex with Men |
|  | **Incidence** *(Median, IQR)* | **Cumulative PIA** *(Median, IQR)* | **Total EPT Doses Taken** *(Median, IQR)* | **Per-Capita Times Infected** *(Median, IQR)* |
| **Reference Model** | 4.64 (2.66, 6.95) | --- | --- | 0.47 (0.34, 0.59) |
| **Provision to Main Partners\*** |  |  |  |  |
| 50% | 3.16 (1.68, 5.07) | 0.13 (-0.23, 0.46) | 85 (69, 108) | 0.37 (0.30, 0.49) |
| 60% | 3.44 (2.08, 5.34) | 0.14 (-0.26, 0.38) | 114 (81, 147) | 0.41 (0.30, 0.53) |
| 70% | 3.24 (1.66, 4.79) | 0.19 (-0.18, 0.42) | 123 (91, 158) | 0.38 (0.28, 0.49) |
| 80% | 2.98 (1.40, 4.77) | 0.23 (-0.13, 0.48) | 134 (102, 174) | 0.37 (0.27, 0.48) |
| 90% | 2.65 (1.37, 4.48) | 0.24 (-0.09, 0.47) | 147 (118, 193) | 0.34 (0.27, 0.47) |
| 100% | 2.67 (1.43, 4.27) | 0.22 (-0.20, 0.49) | 164 (129, 213) | 0.35 (0.27, 0.46) |
| **Provision to Casual Partners\*** |  |  |  |  |
| 50% | 1.79 (0.94, 3.14) | 0.35 (0.06, 0.56) | 252 (186, 333) | 0.29 (0.22, 0.40) |
| 60% | 1.50 (0.64, 2.84) | 0.40 (0.11, 0.59) | 288 (218, 367) | 0.29 (0.22, 0.37) |
| 70% | 1.43 (0.57, 2.64) | 0.42 (0.13, 0.60) | 324 (236, 426) | 0.27 (0.19, 0.36) |
| 80% | 1.06 (0.37, 1.91) | 0.45 (0.26, 0.64) | 325 (248, 435) | 0.24 (0.18, 0.32) |
| 90% | 0.91 (0.26, 1.91) | 0.51 (0.30, 0.65) | 371 (263, 447) | 0.24 (0.17, 0.29) |
| 100% | 0.77 (0.20, 1.58) | 0.54 (0.32, 0.68) | 358 (281, 470) | 0.20 (0.16, 0.28) |
| **Provision to One-Time Partners\*** |   |   |   |   |
| 50% | 3.42 (1.92, 5.19) | 0.12 (-0.32, 0.41) | 226 (175, 283) | 0.41 (0.31, 0.52) |
| 60% | 3.13 (1.91, 5.02) | 0.14 (-0.22, 0.45) | 258 (189, 331) | 0.39 (0.29, 0.49) |
| 70% | 3.37 (2.08, 5.34) | 0.13 (-0.29, 0.36) | 320 (257, 405) | 0.41 (0.33, 0.51) |
| 80% | 3.00 (1.80, 4.67) | 0.16 (-0.21, 0.42) | 346 (269, 440) | 0.39 (0.30, 0.49) |
| 90% | 2.99 (1.72, 4.81) | 0.15 (-0.19, 0.44) | 400 (286, 501) | 0.40 (0.29, 0.50) |
| 100% | 2.77 (1.51, 4.36) | 0.23 (-0.11, 0.46) | 409 (312, 514) | 0.36 (0.27, 0.47) |
| IQR: interquartile range (25% and 75% percentiles) of the simulation outcomes; Incidence expressed per 100 person-years at risk at final year of simulation; All outcomes are compared to the reference model.\* 0% Provision to Other Partnership Types |

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| **Supplementary Table 12.** Chlamydia (CT) Incidence Rates, Percent of Infections Averted (PIA), Expedited Partner Therapy (EPT) Doses Taken by Partners, Number of Infections Averted (NIA), and Mean Number of Times Infected by Provision to Non-Index Partner of Expedited Partner Therapy (EPT) Medication among Men Who Have Sex with Men in the United States |
|  | **Incidence** *(Median, IQR)* | **Cumulative PIA** *(Median, IQR)* | **Total EPT Doses****Taken** *(Median, IQR)* | **Per-Capita Times Infected** *(Median, IQR)* |
| **Reference Model** | 6.85 (5.94, 7.85) | --- | --- | 0.72 (0.65, 0.79) |
| **Provision to Main Partners\*** |  |  |  |  |
| 50% | 5.94 (4.82, 7.05) | 0.07 (-0.06, 0.19) | 121 (107, 132) | 0.68 (0.62, 0.74) |
| 60% | 5.89 (4.92, 6.97) | 0.10 (-0.04, 0.20) | 142 (127, 157) | 0.66 (0.60, 0.74) |
| 70% | 5.70 (4.58, 6.53) | 0.11 (-0.03, 0.22) | 161 (145, 179) | 0.65 (0.59, 0.71) |
| 80% | 5.50 (4.49, 6.54) | 0.09 (-0.03, 0.24) | 184 (167, 205) | 0.65 (0.57, 0.71) |
| 90% | 5.55 (4.51, 6.54) | 0.11 (-0.04, 0.22) | 206 (186, 227) | 0.65 (0.59, 0.72) |
| 100% | 5.23 (4.33, 6.17) | 0.13 (0.01, 0.24) | 226 (204, 248) | 0.64 (0.58, 0.69) |
| **Provision to Casual Partners\*** |  |  |  |  |
| 50% | 4.62 (3.95, 5.65) | 0.18 (0.07, 0.29) | 383 (341, 418) | 0.59 (0.54, 0.65) |
| 60% | 4.39 (3.74, 5.35) | 0.20 (0.07, 0.30) | 444 (407, 491) | 0.59 (0.54, 0.64) |
| 70% | 4.18 (3.38, 5.02) | 0.23 (0.11, 0.31) | 510 (464, 554) | 0.57 (0.52, 0.61) |
| 80% | 4.00 (3.16, 4.68) | 0.24 (0.13, 0.34) | 571 (514, 630) | 0.56 (0.50, 0.62) |
| 90% | 3.62 (2.93, 4.34) | 0.28 (0.18, 0.37) | 616 (558, 670) | 0.53 (0.48, 0.58) |
| 100% | 3.44 (2.67, 4.14) | 0.30 (0.19, 0.39) | 663 (599, 742) | 0.52 (0.46, 0.57) |
| **Provision to One-Time Partners\*** |   |   |   |   |
| 50% | 6.24 (5.20, 7.33) | 0.04 (-0.09, 0.16) | 296 (260, 328) | 0.70 (0.61, 0.77) |
| 60% | 6.12 (5.11, 7.10) | 0.06 (-0.09, 0.18) | 347 (313, 377) | 0.68 (0.62, 0.74) |
| 70% | 5.99 (5.03, 7.10) | 0.06 (-0.07, 0.20) | 404 (363, 444) | 0.67 (0.61, 0.75) |
| 80% | 6.26 (5.22, 7.28) | 0.04 (-0.12, 0.17) | 470 (428, 524) | 0.69 (0.63, 0.76) |
| 90% | 5.85 (4.94, 7.09) | 0.06 (-0.10, 0.19) | 514 (462, 566) | 0.68 (0.61, 0.74) |
| 100% | 6.00 (5.02, 6.90) | 0.06 (-0.06, 0.19) | 581 (527, 641) | 0.68 (0.62, 0.74) |
| IQR: interquartile range (25% and 75% percentiles) of the simulation outcomes; Incidence expressed per 100 person-years at risk at final year of simulation; All outcomes are compared to the reference model.\* 0% Provision to Other Partnership Types |

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| **Supplementary Table 13.** Combined Gonorrhea and Chlamydia (NG/CT) Incidence, Percent of Infections Averted (PIA), Per-Capita Number of Times Infected, and Percentages of Partners Provided with EPT Medication Who Have a Prevalent Undiagnosed HIV and Do Not Have NG/CT Infection Across Varying EPT Treatment Success among Men Who Have Sex with Men |
|  | **Incidence** *(Median, IQR)* | **Cumulative PIA** *(Median, IQR)* | **Per-Capita Times Infected** *(Median, IQR)* | **Percentage of Partners Provided With Undiagnosed HIV** *(Median, IQR)* | **Percentage of Partners Provided Without STI** *(Median, IQR)* |
| **Reference Model** | 11.46 (9.55, 14.17) | --- | 1.18 (1.05, 1.34) | --- | --- |
| **EPT Treatment Success** |   |  |   |   |   |
| 100% | 6.05 (4.79, 7.73) | 0.27 (0.13, 0.39) | 0.87 (0.79, 1.00) | 4.16 (3.65, 4.66) | 53.57 (52.39, 54.80) |
| 90% | 6.12 (4.85, 7.91) | 0.26 (0.14, 0.40) | 0.88 (0.76, 0.99) | 4.13 (3.56, 4.77) | 53.68 (52.44, 55.04) |
| 80% | 6.97 (5.45, 8.35) | 0.22 (0.09, 0.35) | 0.93 (0.81, 1.04) | 4.15 (3.68, 4.71) | 53.58 (52.48, 54.92) |
| 70% | 7.34 (5.87, 8.82) | 0.21 (0.08, 0.32) | 0.95 (0.85, 1.05) | 4.09 (3.56, 4.62) | 53.76 (52.62, 54.67) |
| 60% | 7.69 (6.34, 9.34) | 0.20 (0.05, 0.31) | 0.98 (0.86, 1.08) | 4.21 (3.69, 4.74) | 53.80 (52.81, 54.80) |
| 50% | 7.95 (6.14, 9.94) | 0.19 (0.01, 0.32) | 1.00 (0.86, 1.12) | 4.17 (3.69, 4.65) | 53.73 (52.46, 54.93) |
| 40% | 8.79 (6.82, 11.00) | 0.15 (-0.01, 0.28) | 1.02 (0.91, 1.15) | 4.27 (3.72, 4.81) | 53.69 (52.71, 54.94) |
| 30% | 9.30 (7.61, 11.41) | 0.10 (-0.07, 0.23) | 1.07 (0.96, 1.19) | 4.21 (3.76, 4.80) | 53.53 (52.15, 54.73) |
| 20% | 9.98 (8.24, 11.89) | 0.07 (-0.09, 0.22) | 1.11 (1.00, 1.24) | 4.14 (3.76, 4.63) | 53.83 (52.60, 54.80) |
| 10% | 10.58 (8.46, 12.53) | 0.05 (-0.11, 0.19) | 1.13 (1.00, 1.28) | 4.13 (3.74, 4.63) | 53.68 (52.67, 54.74) |
| 0% | 11.46 (9.36, 13.36) | 0.01 (-0.19, 0.18) | 1.18 (1.06, 1.33) | 4.05 (3.67, 4.58) | 53.68 (52.77, 54.83) |
| IQR: interquartile range (25% and 75% percentiles) of the simulation outcomes; Incidence expressed per 100 person-years at risk at final year of simulation; All outcomes are compared to the reference model. Assumed that EPT Coverage among Index Patients is 20%. |

# 15 REFERENCES

1 Goodreau SM, Carnegie NB, Vittinghoff E, *et al.* What drives the US and Peruvian HIV epidemics in men who have sex with men (MSM)? *PLoS One* 2012; **7**: e50522.

2 Goodreau SM, Carnegie NB, Vittinghoff E, *et al.* Can male circumcision have an impact on the HIV epidemic in men who have sex with men? *PLoS One* 2014; **9**: e102960.

3 Carnegie NB, Goodreau SM, Liu A, *et al.* Targeting pre-exposure prophylaxis among men who have sex with men in the United States and Peru: partnership types, contact rates, and sexual role. *J Acquir Immune Defic Syndr* 2015; **69**: 119–25.

4 Jenness SM, Goodreau SM, Rosenberg E, *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 Inf Dis* 2016; **214**: 1800–7.

5 Jenness SM, Weiss KM, Goodreau SM, *et al.* Incidence of Gonorrhea and Chlamydia Following HIV Preexposure Prophylaxis among Men Who Have Sex with Men: A Modeling Study. *Clin Infect Dis* 2017; **65**: 712–8.

6 Handcock MS, Hunter DR, Butts CT, Goodreau SM, Morris M. Statnet : Software tools for the representation, visualization, analysis and simulation of network data. *J Stat Softw* 2008; **24**: 1–11.

7 Sullivan PS, Carballo-Diéguez A, Coates T, *et al.* Successes and challenges of HIV prevention in men who have sex with men. *Lancet* 2012; **380**: 388–99.

8 Krivitsky PN, Handcock MS. A separable model for dynamic networks. *J R Stat Soc Ser B Stat Methodol* 2014; **76**: 29–46.

9 Hunter DR, Handcock MS, Butts CT, Goodreau SM, Morris M. ergm: A Package to Fit, Simulate and Diagnose Exponential-Family Models for Networks. *J Stat Softw* 2008; **24**: nihpa54860.

10 Carnegie NB, Krivitsky PN, Hunter DR, Goodreau SM. An Approximation Method for Improving Dynamic Network Model Fitting. *J Comput Graph Stat* 2015; **24**: 502–19.

11 Krivitsky PN, Handcock MS, Morris M. Adjusting for network size and composition effects in exponential-family random graph models. *Stat Methodol* 2011; **8**: 319–39.

12 Sullivan PS, Rosenberg ES, Sanchez TH, *et al.* Explaining racial disparities in HIV incidence in black and white men who have sex with men in Atlanta, GA: a prospective observational cohort study. *Ann Epidemiol* 2015; **25**: 445–54.

13 Grey JA, Rothenberg RB, Sullivan PS, *et al.* Disassortative Age-Mixing Does Not Explain Differences in HIV Prevalence between Young White and Black MSM: Findings from Four Studies. *PLoS One* 2015; **10**: e0129877.

14 Gray RH, Kigozi G, Serwadda D, *et al.* Male circumcision for HIV prevention in men in Rakai, Uganda: a randomised trial. *Lancet* 2007; **369**: 657–66.

15 Marmor M, Sheppard HW, Donnell D, *et al.* Homozygous and heterozygous CCR5-Delta32 genotypes are associated with resistance to HIV infection. *J Acquir Immune Defic Syndr* 2001; **27**: 472–81.

16 Zimmerman PA, Buckler-White A, Alkhatib G, *et al.* Inherited resistance to HIV-1 conferred by an inactivating mutation in CC chemokine receptor 5: studies in populations with contrasting clinical phenotypes, defined racial background, and quantified risk. *Mol Med* 1997; **3**: 23–36.

17 U.S. Census Bureau. National Mortality Data. 2012.

18 Little SJ, McLean AR, Spina CA, Richman DD, Havlir D V. Viral dynamics of acute HIV-1 infection. *J Exp Med* 1999; **190**: 841–50.

19 Leynaert B, Downs AM, de Vincenzi I. Heterosexual transmission of human immunodeficiency virus: variability of infectivity throughout the course of infection. European Study Group on Heterosexual Transmission of HIV. *Am J Epidemiol* 1998; **148**: 88–96.

20 Buchbinder SP, Katz MH, Hessol NA, O’Malley PM, Holmberg SD. Long-term HIV-1 infection without immunologic progression. *AIDS* 1994; **8**: 1123–8.

21 Katz MH, Hessol NA, Buchbinder SP, Hirozawa A, O’Malley P, Holmberg SD. Temporal trends of opportunistic infections and malignancies in homosexual men with AIDS. *J Infect Dis* 1994; **170**: 198–202.

22 Mugavero MJ, Amico KR, Horn T, Thompson MA. The State of Engagement in HIV Care in the United States: From Cascade to Continuum to Control. *Clin Infect Dis* 2013; **57**: 1164–71.

23 Rosenberg ES, Millett GA, Sullivan PS, del Rio C, Curran JW. Understanding the HIV disparities between black and white men who have sex with men in the USA using the HIV care continuum: a modelling study. *Lancet HIV* 2014; **1**: e112–8.

24 Fiebig EW, Wright DJ, Rawal BD, *et al.* Dynamics of HIV viremia and antibody seroconversion in plasma donors: implications for diagnosis and staging of primary HIV infection. *AIDS* 2003; **17**: 1871–9.

25 Beer L, Oster AM, Mattson CL, Skarbinski J, Medical Monitoring Project. Disparities in HIV transmission risk among HIV-infected black and white men who have sex with men, United States, 2009. *AIDS* 2014; **28**: 105–14.

26 Bertolli J, Shouse RL, Beer L, *et al.* Using HIV surveillance data to monitor missed opportunities for linkage and engagement in HIV medical care. *Open AIDS J* 2012; **6**: 131–41.

27 Chu H, Gange SJ, Li X, *et al.* The effect of HAART on HIV RNA trajectory among treatment-naïve men and women: a segmental Bernoulli/lognormal random effects model with left censoring. *Epidemiology* 2010; **21 Suppl 4**: S25-34.

28 Chun T-W, Carruth L, Finzi D, *et al.* Quantification of latent tissue reservoirs and total body viral load in HIV-1 infection. *Nature* 1997; **387**: 183–8.

29 Hall HI, Frazier EL, Rhodes P, *et al.* Differences in Human Immunodeficiency Virus Care and Treatment Among Subpopulations in the United States. *JAMA Intern Med* 2013; **173**: 1337–44.

30 Vittinghoff E, Douglas J, Judson F, McKirnan D, MacQueen K, Buchbinder SP. Per-contact risk of human immunodeficiency virus transmission between male sexual partners. *Am J Epidemiol* 1999; **150**: 306–11.

31 Wilson DP, Law MG, Grulich AE, Cooper DA, Kaldor JM. Relation between HIV viral load and infectiousness: a model-based analysis. *Lancet* 2008; **372**: 314–20.

32 Bellan SE, Dushoff J, Galvani AP, Meyers LA. Reassessment of HIV-1 acute phase infectivity: accounting for heterogeneity and study design with simulated cohorts. *PLoS Med* 2015; **12**: e1001801.

33 Varghese B, Maher JE, Peterman TA, Branson BM, Steketee RW. Reducing the risk of sexual HIV transmission: quantifying the per-act risk for HIV on the basis of choice of partner, sex act, and condom use. *Sex Transm Dis* 2002; **29**: 38–43.

34 Weller SC, Davis-Beaty K. Condom effectiveness in reducing heterosexual HIV transmission. *Cochrane Database Syst Rev* 2002; : CD003255.

35 Chesson HW, Pinkerton SD. Sexually transmitted diseases and the increased risk for HIV transmission: Implications for cost-effectiveness analyses of sexually transmitted disease prevention interventions. *J Acquir Immune Defic Syndr* 2000; **24**: 48–56.

36 Vaughan AS, Kelley CF, Luisi N, *et al.* An application of propensity score weighting to quantify the causal effect of rectal sexually transmitted infections on incident HIV among men who have sex with men. *BMC Med Res Methodol* 2015; **15**: 25.

37 Pathela P, Braunstein SL, Blank S, Schillinger JA. HIV Incidence Among Men With and Those Without Sexually Transmitted Rectal Infections: Estimates From Matching Against an HIV Case Registry. *Clin Infect Dis* 2013; **57**: 1203–9.

38 Chesson HW, Bernstein KT, Gift TL, Marcus JL, Pipkin S, Kent CK. The cost-effectiveness of screening men who have sex with men for rectal chlamydial and gonococcal infection to prevent HIV Infection. *Sex Transm Dis* 2013; **40**: 366–71.

39 Johnson LF, Dorrington RE, Bradshaw D, Coetzee DJ. The role of sexually transmitted infections in the evolution of the South African HIV epidemic. *Trop Med Int Heal* 2012; **17**: 161–8.

40 Pinkerton SD, Layde PM, DiFranceisco W, Chesson HW, NIMH Multisite HIV Prevention Trial Group. All STDs are not created equal: An analysis of the differential effects of sexual behaviour changes on different STDs. *Int J STD AIDS* 2003; **14**: 320–8.

41 Kretzschmar M, Satterwhite C, Leichliter J, Berman S. Effects of screening and partner notification on Chlamydia positivity in the United States: a modeling study. *Sex Transm Dis* 2012; **39**: 325–31.

42 Kretzschmar M, Welte R, van den Hoek A, Postma MJ. Comparative model-based analysis of screening programs for Chlamydia trachomatis infections. *Am J Epidemiol* 2001; **153**: 90–101.

43 Welte R, Postma M, Leidl R, Kretzschmar M. Costs and effects of chlamydial screening: dynamic versus static modeling. *Sex Transm Dis* 2005; **32**: 474–83.

44 Turner KME, Adams EJ, Gay N, Ghani AC, Mercer C, Edmunds WJ. Developing a realistic sexual network model of chlamydia transmission in Britain. *Theor Biol Med Model* 2006; **3**: 3.

45 Johnson LF, Alkema L, Dorrington RE. A Bayesian approach to uncertainty analysis of sexually transmitted infection models. *Sex Transm Infect* 2010; **86**: 169–74.

46 Pinkerton SD, Chesson HW, Layde PM, National Institute of Mental Health Multisite HIV Prevention Trial Group. Utility of behavioral changes as markers of sexually transmitted disease risk reduction in sexually transmitted disease/HIV prevention trials. *J Acquir Immune Defic Syndr* 2002; **31**: 71–9.

47 Stigum H, Magnus P, Veierod M, Bakketeig LS. Impact on Sexually Transmitted Disease Spread of Increased Condom Use by Young Females, 1987–1992. *Int J Epidem* 1995; **24**: 813–20.

48 Vickerman P, Watts C, Peeling RW, Mabey D, Alary M. Modelling the cost effectiveness of rapid point of care diagnostic tests for the control of HIV and other sexually transmitted infections among female sex workers. *Sex Transm Infect* 2006; **82**: 403–12.

49 Althaus CL, Heijne JCM, Herzog SA, Roellin A, Low N. Individual and population level effects of partner notification for Chlamydia trachomatis. *PLoS One* 2012; **7**: e51438.

50 Andersen B, Gundgaard J, Kretzschmar M, Olsen J, Welte R, Oster-Gaard L. Prediction of costs, effectiveness, and disease control of a population-based program using home sampling for diagnosis of urogenital Chlamydia trachomatis infections. *Sex Transm Dis* 2006; **33**: 407–15.

51 Davies B, Anderson S-J, Turner KME, Ward H. How robust are the natural history parameters used in chlamydia transmission dynamic models? A systematic review. *Theor Biol Med Model* 2014; **11**: 8.

52 Heijne JCM, Herzog SA, Althaus CL, Tao G, Kent CK, Low N. Insights into the timing of repeated testing after treatment for Chlamydia trachomatis: data and modelling study. *Sex Transm Infect* 2013; **89**: 57–62.

53 Hui BB, Gray RT, Wilson DP, *et al.* Population movement can sustain STI prevalence in remote Australian indigenous communities. *BMC Infect Dis* 2013; **13**: 188.

54 Freeman EE, Orroth KK, White RG, *et al.* Proportion of new HIV infections attributable to herpes simplex 2 increases over time: simulations of the changing role of sexually transmitted infections in sub-Saharan African HIV epidemics. *Sex Transm Infect* 2007; **83 Suppl 1**: i17-24.

55 Pinkerton SD, Chesson HW, Crosby RA, Layde PM. Linearity and nonlinearity in HIV/STI transmission: implications for the evaluation of sexual risk reduction interventions. *Eval Rev* 2011; **35**: 550–65.

56 Swinton J, Garnett GP, Brunham RC, Anderson RM. Gonococcal infection, infertility, and population growth: I. Endemic states in behaviourally homogeneous growing populations. *IMA J Math Appl Med Biol* 1992; **9**: 107–26.

57 Gopalappa C, Huang Y-LA, Gift TL, Owusu-Edusei K, Taylor M, Gales V. Cost-effectiveness of screening men in Maricopa County jails for chlamydia and gonorrhea to avert infections in women. *Sex Transm Dis* 2013; **40**: 776–83.

58 Gray RT, Beagley KW, Timms P, Wilson DP. Modeling the impact of potential vaccines on epidemics of sexually transmitted Chlamydia trachomatis infection. *J Inf Dis* 2009; **199**: 1680–8.

59 Schmid B V, Kretzschmar M. Determinants of sexual network structure and their impact on cumulative network measures. *PLoS Comput Biol* 2012; **8**: e1002470.

60 Turner KME, Round J, Horner P, *et al.* An early evaluation of clinical and economic costs and benefits of implementing point of care NAAT tests for Chlamydia trachomatis and Neisseria gonorrhoea in genitourinary medicine clinics in England. *Sex Transm Infect* 2014; **90**: 104–11.

61 Turner KME, Adams EJ, Lamontagne DS, Emmett L, Baster K, Edmunds WJ. Modelling the effectiveness of chlamydia screening in England. *Sex Transm Infect* 2006; **82**: 496–502.

62 Althaus CL, Heijne JCM, Low N. Towards more robust estimates of the transmissibility of Chlamydia trachomatis. *Sex Transm Dis* 2012; **39**: 402–4.

63 Pinkerton SD, Layde PM, NIMH multisite HIV prevention trial group. Using sexually transmitted disease incidence as a surrogate marker for HIV incidence in prevention trials: a modeling study. *Sex Transm Dis* 2002; **29**: 298–307.

64 Owusu-Edusei K, Hoover KW, Gift TL. Cost-effectiveness of opt-out chlamydia testing for high-risk young women in the US. *Am J Prev Med* 2016; **51**: 216–24.

65 de Vries R, van Bergen JEAM, de Jong-van den Berg LTW, Postma MJ, PILOT-CT Study Group. Systematic screening for Chlamydia trachomatis: estimating cost-effectiveness using dynamic modeling and Dutch data. *Value Heal* 2006; **9**: 1–11.

66 Clarke J, White KAJ, Turner K. Approximating optimal controls for networks when there are combinations of population-level and targeted measures available: chlamydia infection as a case-study. *Bull Math Biol* 2013; **75**: 1747–77.

67 Kretzschmar M, van Duynhoven YT, Severijnen AJ. Modeling prevention strategies for gonorrhea and Chlamydia using stochastic network simulations. *Am J Epidemiol* 1996; **144**: 306–17.

68 Roberts TE, Robinson S, Barton PM, *et al.* Cost effectiveness of home based population screening for Chlamydia trachomatis in the UK: economic evaluation of chlamydia screening studies (ClaSS) project. *BMJ* 2007; **335**: 291.

69 Schmid B V, Over EAB, van den Broek IVF, *et al.* Effects of population based screening for Chlamydia infections in the Netherlands limited by declining participation rates. *PLoS One* 2013; **8**: e58674.

70 Xiridou M, Vriend HJ, Lugner AK, *et al.* Modelling the impact of chlamydia screening on the transmission of HIV among men who have sex with men. *BMC Infect Dis* 2013; **13**: 436.

71 Beck EC, Birkett M, Armbruster B, Mustanski B. A data-driven simulation of HIV spread among young men who have sex with men: Role of age and race mixing and STIs. *J Acquir Immune Defic Syndr* 2015; **70**: 186–94.

72 Tuli K, Kerndt PR. Preventing sexually transmitted infections among incarcerated men who have sex with men: a cost-effectiveness analysis. *Sex Transm Dis* 2009; **36**: S41-8.

73 Darrow WW. Condom use and use-effectiveness in high-risk populations. *Sex Transm Dis* 1989; **16**: 157–60.

74 Joesoef MR, Linnan M, Barakbah Y, Idajadi A, Kambodji A, Schulz K. Patterns of sexually transmitted diseases in female sex workers in Surabaya, Indonesia. *Int J STD AIDS* 1997; **8**: 576–80.

75 Korenromp EL, Van Vliet C, Grosskurth H, *et al.* Model-based evaluation of single-round mass treatment of sexually transmitted diseases for HIV control in a rural African population. *AIDS* 2000; **14**: 573–93.

76 Marseille E, Kahn JG, Billinghurst K, Saba J. Cost-effectiveness of the female condom in preventing HIV and STDs in commercial sex workers in rural South Africa. *Soc Sci Med* 2001; **52**: 135–48.

77 Armbruster B, Brandeau ML. Contact tracing to control infectious disease: when enough is enough. *Heal Care Manag Sci* 2007; **10**: 341–55.

78 Chen MI, Ghani AC, Edmunds J. Mind the gap: the role of time between sex with two consecutive partners on the transmission dynamics of gonorrhea. *Sex Transm Dis* 2008; **35**: 435–44.

79 Garnett GP, Swinton J, Brunham RC, Anderson RM. Gonococcal infection, infertility, and population growth: II. The influence of heterogeneity in sexual behaviour. *IMA J Math Appl Med Biol* 1992; **9**: 127–44.

80 Ghani AC, Aral SO. Patterns of sex worker-client contacts and their implications for the persistence of sexually transmitted infections. *J Inf Dis* 2005; **191**: S34–41.

81 Ghani AC, Swinton J, Garnett GP. The role of sexual partnership networks in the epidemiology of gonorrhea. *Sex Transm Dis* 1997; **24**: 45–56.

82 Hazel A, Marino S, Simon C. An anthropologically based model of the impact of asymptomatic cases on the spread of Neisseria gonorrhoeae. *J R Soc Interface* 2015; **12**: 20150067.

83 Hui BB, Ryder N, Su J-Y, *et al.* Exploring the benefits of molecular testing for gonorrhoea antibiotic resistance surveillance in remote settings. *PLoS One* 2015; **10**: e0133202.

84 McCluskey CC, Roth E, van den Driessche P. Implication of Ariaal sexual mixing on gonorrhea. *Am J Hum Biol* 2005; **17**: 293–301.

85 Turner KME, Garnett GP, Ghani AC, Sterne JAC, Low N. Investigating ethnic inequalities in the incidence of sexually transmitted infections: mathematical modelling study. *Sex Transm Infect* 2004; **80**: 379–85.

86 Edwards R, Kim S, van den Driessche P. A multigroup model for a heterosexually transmitted disease. *Math Biosci* 2010; **224**: 87–94.

87 Craig AP, Gray RT, Edwards JL, *et al.* The potential impact of vaccination on the prevalence of gonorrhea. *Vaccine* 2015; **33**: 4520–5.

88 Althouse BM, Hébert-Dufresne L. Epidemic cycles driven by host behaviour. *J R Stat Soc Ser B Stat Methodol* 2014; **11**: 20140575.

89 Boily MC, Anderson RM. Human immunodeficiency virus transmission and the role of other sexually transmitted diseases. Measures of association and study design. *Sex Transm Dis* 1996; **23**: 312–32.

90 Garnett GP, Mertz KJ, Finelli L, Levine WC, St Louis ME. The transmission dynamics of gonorrhoea: modelling the reported behaviour of infected patients from Newark, New Jersey. *Philos Trans R Soc L B Biol Sci* 1999; **354**: 787–97.

91 Xiridou M, Soetens LC, Koedijk FDH, VAN DER Sande MAB, Wallinga J. Public health measures to control the spread of antimicrobial resistance in Neisseria gonorrhoeae in men who have sex with men. *Epidemiol Infect* 2015; **143**: 1575–84.

92 Morin BR, Medina-Rios L, Camacho ET, Castillo-Chavez C. Static behavioral effects on gonorrhea transmission dynamics in a MSM population. *J Theor Biol* 2010; **267**: 35–40.

93 Xiridou M, Lugnér A, de Vries HJC, *et al.* Cost-effectiveness of dual antimicrobial therapy for gonococcal infections among men who have sex with men in the Netherlands. *Sex Transm Dis* 2016; **43**: 542–8.

94 Hui B, Fairley CK, Chen M, *et al.* Oral and anal sex are key to sustaining gonorrhoea at endemic levels in MSM populations: a mathematical model. *Sex Transm Infect* 2015; **91**: 365–9.

95 Farley TA, Cohen DA, Elkins W. Asymptomatic sexually transmitted diseases: The case for screening. *Prev Med (Baltim)* 2003; **36**: 502–9.

96 Kent CK, Chaw JK, Wong W, *et al.* Prevalence of rectal, urethral, and pharyngeal chlamydia and gonorrhea detected in 2 clinical settings among men who have sex with men: San Francisco, California, 2003. *Clin Infect Dis* 2005; **41**: 67–74.

97 Gift TL, Kissinger P, Mohammed H, Leichliter JS, Hogben M, Golden MR. The cost and cost-effectiveness of expedited partner therapy compared with standard partner referral for the treatment of chlamydia or gonorrhea. *Sex Transm Dis* 2011; **38**: 1067–73.

98 Tuite AR, Jayaraman GC, Allen VG, Fisman DN. Estimation of the burden of disease and costs of genital Chlamydia trachomatis infection in Canada. *Sex Transm Dis* 2012; **39**: 260–7.

99 White PJ, Ward H, Cassell JA, Mercer CH, Garnett GP. Vicious and virtuous circles in the dynamics of infectious disease and the provision of health care: gonorrhea in Britain as an example. *J Inf Dis* 2005; **192**: 824–36.

100 Vickerman P, Ndowa F, O’Farrell N, Steen R, Alary M, Delany-Moretlwe S. Using mathematical modelling to estimate the impact of periodic presumptive treatment on the transmission of sexually transmitted infections and HIV among female sex workers. *Sex Transm Infect* 2010; **86**: 163–8.

101 Brunham RC, Pourbohloul B, Mak S, White R, Rekart ML. The unexpected impact of a Chlamydia trachomatis infection control program on susceptibility to reinfection. *J Inf Dis* 2005; **192**: 1836–44.

102 Althaus CL, Heijne JCM, Roellin A, Low N. Transmission dynamics of Chlamydia trachomatis affect the impact of screening programmes. *Epidemics* 2010; **2**: 123–31.

103 Boily MC, Lowndes C, Alary M. The impact of HIV epidemic phases on the effectiveness of core group interventions: insights from mathematical models. *Sex Transm Infect* 2002; **78 Suppl 1**: i78-90.

104 Centers for Disease Control and Prevention. 2015 STD Treatment Guidelines. *MMWR Recomm Reports* 2015; **64**. http://www.cdc.gov/std/tg2015/default.htm.

105 Hoots BE, Torrone EA, Bernstein KT, Paz-Bailey G, NHBS Study Group. Self-reported chlamydia and gonorrhea testing and diagnosis among men who have sex with men 20 U.S. cities, 2011 and 2014. *Sex Transm Dis* 2018; : 1.

106 An Q, Wejnert C, Bernstein K, Paz-Bailey G. Syphilis Screening and Diagnosis Among Men Who Have Sex With Men, 2008-2014, 20 U.S. Cities. *JAIDS J Acquir Immune Defic Syndr* 2017; **75**: S363–9.

107 Hoots BE, Torrone E, Bernstein KT, Paz-Bailey G. Chlamydia and gonorrhea testing and diagnosis among men who have sex with men — 20 U.S. cities, 2011 and 2014. *Unpublished* 2017.

108 Schillinger JA, Gorwitz R, Rietmeijer C, Golden MR. The Expedited Partner Therapy Continuum. *Sex Transm Dis* 2016; **43**: S63–75.

109 Kerani RP, Fleming M, DeYoung B, Golden MR. A randomized, controlled trial of inSPOT and patient-delivered partner therapy for gonorrhea and chlamydial infection among men who have sex with men. *Sex Transm Dis* 2011; **38**: 941–6.

110 Stenger MR, Kerani RP, Bauer HM, *et al.* Patient-Reported Expedited Partner Therapy for Gonorrhea in the United States: Findings of the STD Surveillance Network 2010-2012. *Sex Transm Dis* 2015; **42**: 470–4.

111 Oliver A, Rogers M, Schillinger JA. The Impact of Prescriptions on Sex Partner Treatment Using Expedited Partner Therapy for Chlamydia trachomatis Infection, New York City, 2014–2015. *Sex Transm Dis* 2016; **43**: 673–8.

112 Vaidya S, Johnson K, Rogers M, Nash D, Schillinger JA. Predictors of Index Patient Acceptance of Expedited Partner Therapy for Chlamydia trachomatis Infection and Reasons for Refusal, Sexually Transmitted Disease Clinics, New York City, 2011 to 2012. *Sex Transm Dis* 2014; **41**: 690–4.

113 Golden MR, Hughes JP, Brewer DD, *et al.* Evaluation of a Population-Based Program of Expedited Partner Therapy for Gonorrhea and Chlamydial Infection. *Sex Transm Dis* 2007; **PAP**. DOI:10.1097/01.olq.0000258319.54316.06.

114 Golden MR, Kerani RP, Stenger M, *et al.* Uptake and population-level impact of expedited partner therapy (EPT) on Chlamydia trachomatis and Neisseria gonorrhoeae: the Washington State community-level randomized trial of EPT. *PLoS Med* 2015; **12**: e1001777.

115 Hogben M, McCree DH, Golden MR. Patient-delivered partner therapy for sexually transmitted diseases as practiced by U.S. physicians. *Sex Transm Dis* 2005; **32**: 101–5.

116 Rogers ME, Opdyke KM, Blank S, Schillinger JA. Patient-Delivered Partner Treatment and Other Partner Management Strategies for Sexually Transmitted Diseases Used by New York City Healthcare Providers. *Sex Transm Dis* 2007; **34**: 88–92.

117 Bilardi JE, Fairley CK, Hopkins CA, *et al.* Experiences and Outcomes of Partner Notification Among Men and Women Recently Diagnosed With Chlamydia and Their Views on Innovative Resources Aimed at Improving Notification Rates. *Sex Transm Dis* 2010; **37**: 253–8.

118 Schillinger JA, Kissinger P, Calvet H, *et al.* Patient-delivered partner treatment with azithromycin to prevent repeated Chlamydia trachomatis infection among women: a randomized, controlled trial. *Sex Transm Dis* 2003; **30**: 49–56.

119 Cameron ST, Glasier A, Scott G, *et al.* Novel interventions to reduce re-infection in women with chlamydia: a randomized controlled trial. *Hum Reprod* 2009; **24**: 888–95.

120 Golden MR, Whittington WLH, Handsfield HH, *et al.* Effect of Expedited Treatment of Sex Partners on Recurrent or Persistent Gonorrhea or Chlamydial Infection. *N Engl J Med* 2005; **352**: 676–85.

121 Mohammed H, Leichliter JS, Schmidt N, Farley TA, Kissinger P. Does Patient-Delivered Partner Treatment Improve Disclosure for Treatable Sexually Transmitted Diseases? *AIDS Patient Care STDS* 2010; **24**: 183–8.

122 Clark JL, Segura ER, Oldenburg CE, *et al.* Expedited Partner Therapy (EPT) increases the frequency of partner notification among MSM in Lima, Peru: a pilot randomized controlled trial. *BMC Med* 2017; **15**: 94.

123 Kerani RP, Fleming M, Golden MR. Acceptability and intention to seek medical care after hypothetical receipt of patient-delivered partner therapy or electronic partner notification postcards among men who have sex with men: the partner’s perspective. *Sex Transm Dis* 2013; **40**: 179–85.

124 Kissinger P, Mohammed H, Richardson-Alston G, *et al.* Patient-delivered partner treatment for male urethritis: a randomized, controlled trial. *Clin Infect Dis* 2005; **41**: 623–9.

125 Shiely F, Hayes K, Thomas KK, *et al.* Expedited partner therapy: a robust intervention. *Sex Transm Dis* 2010; **37**: 602–7.

126 Okah E, Arya V, Rogers M, Kim M, Schillinger JA. Sentinel Surveillance for Expedited Partner Therapy Prescriptions Using Pharmacy Data, in 2 New York City Neighborhoods, 2015. *Sex Transm Dis* 2017; **44**: 104–8.

127 Stephens SC, Bernstein KT, Katz MH, Philip SS, Klausner JD. The effectiveness of patient-delivered partner therapy and chlamydial and gonococcal reinfection in San Francisco. *Sex Transm Dis* 2010; **37**: 525–9.

128 Kissinger P, Brown R, Reed K, *et al.* Effectiveness of patient delivered partner medication for preventing recurrent Chlamydia trachomatis. *Sex Transm Infect* 1998; **74**: 331–3.

129 McNulty A, Teh MF, Freedman E. Patient delivered partner therapy for chlamydial infection--what would be missed? *Sex Transm Dis* 2008; **35**: 834–6.

130 Khan A, Fortenberry JD, Juliar BE, Tu W, Orr DP, Batteiger BE. The prevalence of chlamydia, gonorrhea, and trichomonas in sexual partnerships: implications for partner notification and treatment. *Sex Transm Dis* 2005; **32**: 260–4.

131 Rosenberg ES, Grey JA, Sanchez TH, Sullivan PS. Rates of Prevalent HIV Infection, Prevalent Diagnoses, and New Diagnoses Among Men Who Have Sex With Men in US States, Metropolitan Statistical Areas, and Counties, 2012-2013. *JMIR public Heal Surveill* 2016; **2**: e22.

132 Kelley CF, Vaughan AS, Luisi N, *et al.* The effect of high rates of bacterial sexually transmitted infections on HIV incidence in a cohort of black and white men who have sex with men in Atlanta, Georgia. *AIDS Res Hum Retroviruses* 2015; **31**: 587–92.

133 Hernández-Romieu AC, Sullivan PS, Rothenberg R, *et al.* Heterogeneity of HIV prevalence among the sexual networks of black and white men who have sex with men in Atlanta: Illuminating a mechanism for increased HIV risk for young black men who have sex with men. *Sex Transm Dis* 2015; **42**: 505–12.

134 Korenromp EL, Bakker R, De Vlas SJ, Robinson NJ, Hayes R, Habbema JDF. Can behavior change explain increases in the proportion of genital ulcers attributable to herpes in sub-Saharan Africa? A simulation modeling study. *Sex Transm Dis* 2002; **29**: 228–38.

135 Centers for Disease Control and Prevention. Guidance on the Use of Expedited Partner Therapy in the Treatment of Gonorrhea. http://www.cdc.gov/std/ept/gc-guidance.htm (accessed Sept 28, 2016).

136 Scott HM, Klausner JD. Sexually transmitted infections and pre-exposure prophylaxis: challenges and opportunities among men who have sex with men in the US. *AIDS Res Ther* 2016; **13**: 5.

137 Gray RT, Hoare A, Prestage GP, Donovan B, Kaldor JM, Wilson DP. Frequent testing of highly sexually active gay men is required to control syphilis. *Sex Transm Dis* 2010; **37**: 298–305.

138 Roberts CP, Klausner JD. Global challenges in human immunodeficiency virus and syphilis coinfection among men who have sex with men. *Expert Rev Anti Infect Ther* 2016; **14**: 1037–46.

139 Ferreira A, Young T, Mathews C, Zunza M, Low N. Strategies for partner notification for sexually transmitted infections, including HIV. *Cochrane Database Syst Rev* 2013; published online Oct 3. DOI:10.1002/14651858.CD002843.pub2.

140 Katz DA, Dombrowski JC, Kerani RP, *et al.* Integrating HIV Testing as an Outcome of STD Partner Services for Men Who Have Sex with Men. *AIDS Patient Care STDS* 2016; **30**: 208–14.

141 Centers for Disease Control and Prevention. Legal Status of Expedited Partner Therapy. http://www.cdc.gov/std/ept/legal/default.htm (accessed Oct 4, 2018).

142 Malek AM, Chang C-CH, Clark DB, Cook RL. Delay in Seeking Care for Sexually Transmitted Diseases in Young Men and Women Attending a Public STD Clinic. *Open AIDS J* 2013; **7**: 7–13.

143 Kissinger PJ, Reilly K, Taylor SN, Leichliter JS, Rosenthal S, Martin DH. Early repeat Chlamydia trachomatis and Neisseria gonorrhoeae infections among heterosexual men. *Sex Transm Dis* 2009; **36**: 498–500.

144 Bell G, Potterat J. Partner notification for sexually transmitted infections in the modern world: a practitioner perspective on challenges and opportunities. *Sex Transm Infect* 2011; **87 Suppl 2**: ii34-6.

145 Katz DA, Dombrowski JC, Bell TR, Kerani RP, Golden MR. HIV Incidence Among Men Who Have Sex With Men After Diagnosis With Sexually Transmitted Infections. *Sex Transm Dis* 2016; **43**: 249–54.

146 Stekler J, Bachmann L, Brotman RM, *et al.* Concurrent sexually transmitted infections (STIs) in sex partners of patients with selected STIs: implications for patient-delivered partner therapy. *Clin Infect Dis* 2005; **40**: 787–93.

147 Golden MR, Estcourt CS. Barriers to the implementation of expedited partner therapy. *Sex Transm Infect* 2011; **87 Suppl 2**: ii37-8.

148 Turner K, Adams E, Grant A, *et al.* Costs and cost effectiveness of different strategies for chlamydia screening and partner notification: an economic and mathematical modelling study. *BMJ* 2011; **342**: c7250.

149 Hodge JG, Pulver A, Hogben M, Bhattacharya D, Brown EF, Brown EF. Expedited partner therapy for sexually transmitted diseases: assessing the legal environment. *Am J Public Health* 2008; **98**: 238–43.

150 Committee on Gynecologic Practice, Committee on Adolescent Health Care. Expedited Partner Therapy in the Management of Gonorrhea and Chlamydial Infection - ACOG. 2018 https://www.acog.org/Clinical-Guidance-and-Publications/Committee-Opinions/Committee-on-Gynecologic-Practice/Expedited-Partner-Therapy.

151 Hogben M, Kidd S, Burstein GR. Expedited partner therapy for sexually transmitted infections. *Curr Opin Obstet Gynecol* 2012; **24**: 299–304.

152 Mercer CH, Sutcliffe L, Johnson AM, *et al.* How much do delayed healthcare seeking, delayed care provision, and diversion from primary care contribute to the transmission of STIs? *Sex Transm Infect* 2007; **83**: 400–5.

153 Trelle S, Shang A, Nartey L, Cassell J a, Low N. Improved effectiveness of partner notification for patients with sexually transmitted infections: systematic review. *BMJ* 2007; **334**: 354.

154 Katz D. STD Partner Services to Monitor and Promote PrEP Use among Men who have sex with men. In: Conference on Retroviruses and Opportunistic Infections (CROI). 2017.

155 Reid A, Rogers ME, Arya V, Edelstein ZR, Schillinger JA. Pharmacistsʼ Knowledge and Practices Surrounding Expedited Partner Therapy for Chlamydia trachomatis, New York City, 2012 and 2014. *Sex Transm Dis* 2016; **43**: 679–84.

156 Tan WS, Chen M, Ivan M, *et al.* Partner Notification Outcomes for Men Who Have Sex With Men Diagnosed With Syphilis Referred to Partner Notification Officers, Melbourne, Australia. *Sex Transm Dis* 2016; **43**: 685–9.

157 Introcaso CE, Rogers ME, Abbott SA, Gorwitz RJ, Markowitz LE, Schillinger JA. Expedited Partner Therapy in Federally Qualified Health Centers—New York City, 2012. *Sex Transm Dis* 2013; **40**: 881–5.

158 Kissinger PJ. The Challenges of Implementing and Evaluating Prescription Expedited Partner Treatment. *Sex Transm Dis* 2017; **44**: 109–10.

159 Kojima N, Davey DJ, Klausner JD. Pre-exposure prophylaxis for HIV infection and new sexually transmitted infections among men who have sex with men. *AIDS* 2016; **30**: 2251–2.

160 Stenger MR, Pathela P, Anschuetz G, *et al.* Increases in the Rate of Neisseria gonorrhoeae Among Gay, Bisexual and Other Men Who Have Sex With Men: Findings From the Sexually Transmitted Disease Surveillance Network 2010-2015. *Sex Transm Dis* 2017; **44**: 393–7.

161 Toni T, Welch D, Strelkowa N, *et al.* Approximate Bayesian computation scheme for parameter inference and model selection in dynamical systems. *J R Soc Interface* 2009; **6**: 187–202.