Observational studies have found mixed results on the impact of jail-based chlamydia screen-and-treat programs on community prevalence. In the absence of controlled trials or prospectively designed studies, dynamic mathematical models that incorporate movements in and out of jail and sexual contacts (including disease transmission) can provide useful information. We explored the impact of jail-based chlamydia screening on a hypothetical community’s prevalence with a deterministic compartmental model focusing on heterosexual transmission. Parameter values were obtained from the published literature. Two analyses were conducted. One used national values (large community); the other used values reported among African Americans—the population with the highest incarceration rates and chlamydia burden (small community). A comprehensive sensitivity analysis was carried out. For the large-community analysis, chlamydia prevalence decreased by 13% (from 2.3% to 2.0%), and based on the ranges of parameter values (including screening coverage of 10%–100% and a post-screening treatment rate of 50%–100%) used in the sensitivity analysis, this decrease ranged from 0.1% to 58%. For the small-community analysis, chlamydia prevalence decreased by 54% (from 4.6% to 2.1%). Jail-based chlamydia screen-and-treat programs have the potential to reduce chlamydia prevalence in communities with high incarceration rates. However, the magnitude of this potential decrease is subject to considerable uncertainty.

chlamydia; jail-based screening; mathematical transmission modeling

Abbreviations: LHS, Latin hypercube sampling; PRCC, partial rank correlation coefficient; STD, sexually transmitted disease.

In 2010, a total of 1,307,893 chlamydial infections were reported in the United States, making it the most commonly reported disease (1). Because the primary burden of adverse sequelae from chlamydia is borne by women, including pelvic inflammatory disease, ectopic pregnancy, and infertility (2), most interventions have focused on reducing infection and transmission to women.

The prevalence of chlamydia and other sexually transmitted diseases (STDs) is higher among persons in correctional institutions than in the general population (3). The United States has the highest incarceration rate of any country in the world (4). There also are substantial disparities in terms of who is incarcerated. Male incarceration rates are 10 times higher than female rates, and the proportion of males aged 18–39 years currently incarcerated varies by race/ethnicity: 9.7% of African Americans, 3.4% of Hispanics, and 1.6% of non-Hispanic whites (5). Given the unique opportunities correctional facilities present to reach underserved and high-risk populations, some authors have suggested that correctional health be given public health priority and be made an integral part of community health efforts to control and prevent the spread of STDs and other infectious diseases (6–11). Consequently, there have been a number of jail-based screen-and-treat programs for bacterial STDs in the United States, with treatment coverage ranging from 45% to 95% (3, 8, 12–20). In cities that have performed screening in juvenile detention centers and jails, 4- to 15-fold more chlamydial infections have been identified in jails than in juvenile facilities, depending upon how comprehensive screening was in the jails (21, 22). This is probably because the prevalence of infection among males, in a given community, is higher among young men in jail (ages 18–30 years) than among boys (younger than age 18 years) in juvenile detention and the
prevalence of infection among young women in jails is similar to that of girls in juvenile detention (21, 22): There are 9 times more people aged 18–35 years incarcerated in jails than adolescents incarcerated in youth detention facilities (5, 23), and males make up 90% of the incarcerated population (5). Thus, the higher prevalence of infection among young men in jails and the greater number of high-risk young adults in jails suggest that screening of young adults in jail could have a substantially greater impact than screening of adolescents in juvenile detention. In addition, jail-based programs have the potential to reduce transmission by substantially reducing the duration of infectiousness, particularly for asymptomatic infections such as chlamydia.

In 2 recent studies carried out in large US cities (Chicago, Illinois, and San Francisco, California), investigators concluded that jail-based screening might have caused the observed reduction in the burden of chlamydia in their respective communities (14, 24). However, another recent study using data from Philadelphia, Pennsylvania, found no evidence to support the hypothesis that jail screening contributed to decreases in chlamydia prevalence (25).

To our knowledge, there have been no controlled trials or other prospectively designed studies to assess the impact of jail-based screen-and-treat programs on the burden of disease among heterosexuals in a community. In view of this, our main objective in this study was to examine the potential impact of a jail-based screen-and-treat program for chlamydia on the disease burden among heterosexuals aged 18–35 years in a community using a simple (and exploratory) dynamic mathematical transmission model.

MATERIALS AND METHODS

We constructed a deterministic population-based compartmental model of chlamydia transmission, based on previously published models (26–30). Data for the model were assembled from the published literature, and base-case parameter values were selected such that the resulting chlamydia prevalence was close to national averages. The model yielded a preintervention equilibrium prevalence of 2.3% for both men and women, versus a population prevalence of 1.9% for men and 2.6% for women for the age group used in this analysis (i.e., 18–35 years) (31). We conducted 2 analyses with the model: one reflecting a large community with overall low incarceration rates similar to the US average and another depicting a screening program in a smaller community with higher incarceration rates similar to that observed in some subpopulations (such as African Americans) in the United States.

We assumed a hypothetically large community of 2 million people (half men and half women between 18 and 35 years of age), and we allowed for people to age in and out of the population. In our model, participants were in 1 of 2 locations (the community or jail) and in 1 of 4 compartments reflecting chlamydia status—susceptible, exposed, infectious and symptomatic, or infectious and asymptomatic (see Figure 1). Those in jail were assumed to have no sexual contacts during their time of incarceration, either with other incarcerated individuals or with persons in the community (see Figure 1).

The number of people entering jail (i.e., becoming incarcerated) each day (100 men, 20 women) was based on the overall nationwide incarceration rates (5, 32, 33). We assumed that all residents in the community were exclusively heterosexual and were sexually active. We categorized people into 2 sexual-activity classes (for both men and women) based on the annual number of sex partners. We included a mixing parameter (e) to control for the degree to which people preferentially select partners from the same sexual-activity class (versus the alternative of selecting partners randomly from the population) and set the mixing parameter between the 2 sexual-activity classes to 0.5 for the base-case scenario (26). Other than with regard to sexual activity, mixing was random (i.e., no assortative mixing based on race/ethnicity or age was incorporated; persons in the model were not differentiated by these characteristics).

Base-case screening coverage in jail was 90% for both sexes at intake, and the postscreening treatment rate was 90%, meaning that approximately 80% of infected inmates were both screened and treated (3). In addition to treatment resulting from annual chlamydia screening for women in the community through routine use of health-care services (34, 35), we assumed treatment of symptomatic persons in both locations (jail and community). Model parameters, base-case values, ranges, and sources are presented in Table 1. Details on model equations and symbol descriptions are presented in the Appendix.

We determined the steady-state prevalence (i.e., when the estimated prevalence was greater than 0 and remained constant over time) in both the community and jail, before and after the onset of the screen-and-treat program, and computed the screening program’s impact as the percentage decrease in the estimated community prevalence.

We conducted comprehensive sensitivity and uncertainty analyses using Latin hypercube sampling (LHS) for the large-community analysis. The LHS is an efficient method for assessing variability and robustness of transmission model results (36, 37). The LHS is a type of Monte Carlo sampling that is computationally more efficient (36). The advantage of LHS is that all values within the specified range have the same likelihood of being selected for each of the simulations without repetition, and the total number of runs required is substantially lower. Additionally, it is more suitable for conducting partial rank correlation coefficient (PRCC) analyses because it is easier to rank the unique values used. To perform LHS, we assumed that the values for each variable were uniformly distributed between their lower and upper bounds. We created 1,000 random combinations of parameter values by randomly choosing (without replacement) from 1,000 equiprobable parameter value intervals using the ranges provided in Table 1. Combinations that did not produce steady-state prevalence rates were dropped from the LHS sample. We then ranked the variables according to their influence on the calculated impact measures using the PRCC method (36, 37).

Given that the parameters of interest in this study were jail screening and treatment rates, we used wider ranges for both in the initial sensitivity analyses (i.e., 10%–100% for screening and 50%–100% for postscreening treatment). In order to examine the potential impact of the most efficient
jail-based screening programs, we then repeated the sensitivity analyses using 80%–100% for both screening coverage and postscreening treatment rate.

We repeated the analysis assuming a relatively small community of 20,000 people (half men and half women aged 18–35 years) with a higher incarceration rate (i.e., 11% (5, 7)), higher program coverage (i.e., 95% screening and treatment rate (3)), and a higher disease burden. The purpose of examining this smaller community was to examine the potential impact in a given neighborhood or a particular racial/ethnic group (such as African Americans), with comparatively higher incarceration rates and a higher chlamydia burden. Thus, we selected parameter values within the ranges provided in Table 1 that resulted in a steady-state prevalence twice as high as the national estimates used in the large-community analysis (i.e., 4.6% for both men (4.0%) and women (5.1%)). The numbers of arrestees per day for both men and women were estimated on the basis of the jail population and the average number of days spent in jail, as described in the Appendix.

We used Berkeley Madonna, version 8.3.9 (Robert I. Macey and George F. Oster, Berkeley, California), to solve the system of differential equations. We used a fixed step size of 1 day and approximated the system of differential equations using difference equations. We reprogrammed the model in Microsoft Excel, version 2007 (Microsoft Corporation, Redmond, Washington), for validation and for creating the LHS table that was used for the sensitivity and uncertainty analyses.

RESULTS

Large-community analysis

Based on the program coverage values used, the steady-state chlamydia prevalence in the community for men and women combined decreased by 13% (from 2.3% to 2.0%) in the large-community analysis within approximately 3 years of the onset of the program (see Figure 2). The estimated impact was 15.8% (community prevalence decreased from 1.9% to 1.6%) for men and 11.5% (community prevalence decreased from 2.6% to 2.3%) for women. The impact on the prevalence of infection among people in jail for the large-community analysis was a 63.6% decline (jail prevalence for both men and women decreased from 12.1% to 4.4%).

Small-community analysis

Results from the additional analysis in which we assumed a small community with a higher incarceration
Table 1. Parameters and Base-Case Values Used in a Model Investigating the Impact of a Jail-based Chlamydia Screening Program on a Hypothetical Community’s Chlamydia Prevalence

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Notation</th>
<th>Men</th>
<th>Women</th>
<th>Reference No(s.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community population (age 18–35 years)</td>
<td>(N_C)</td>
<td>1 million - (N_J)</td>
<td>1 million - (N_J)</td>
<td>5, 32, 33, 51a</td>
</tr>
<tr>
<td>Jail population (age 18–35 years)</td>
<td>(N_J)</td>
<td>5,000</td>
<td>600</td>
<td>5, 32, 33, 51a</td>
</tr>
<tr>
<td>No. of arrestees per day</td>
<td>(u)</td>
<td>100</td>
<td>20</td>
<td>5, 32, 33, 51a</td>
</tr>
<tr>
<td>Average no. of days spent in jail</td>
<td>(\Theta)</td>
<td>50</td>
<td>30</td>
<td>5, 32, 33, 51a</td>
</tr>
<tr>
<td>Duration of symptomatic infection, days</td>
<td>(1/\alpha_1)</td>
<td>14</td>
<td>28</td>
<td>5, 32, 53</td>
</tr>
<tr>
<td>Duration of asymptomatic infection, days</td>
<td>(1/\alpha_2)</td>
<td>182.5</td>
<td>40</td>
<td>5, 32, 53</td>
</tr>
<tr>
<td>Incubation period, days</td>
<td>(1/\omega)</td>
<td>14</td>
<td>14</td>
<td>5, 32, 53</td>
</tr>
<tr>
<td>Per-contact transmission to opposite sex</td>
<td>(\beta)</td>
<td>0.335</td>
<td>0.25</td>
<td>54–56</td>
</tr>
<tr>
<td>Proportion of symptomatic infections</td>
<td>(\xi)</td>
<td>0.50</td>
<td>0.20</td>
<td>2, 57</td>
</tr>
<tr>
<td>No. of sex partners in last year, high sexual activity</td>
<td>(c(j=2))</td>
<td>13.30</td>
<td>33.26</td>
<td>30, 58, 59</td>
</tr>
<tr>
<td>No. of sex partners in last year, low sexual activity</td>
<td>(c(j=1))</td>
<td>0.90</td>
<td>0.88</td>
<td>30, 58, 59</td>
</tr>
<tr>
<td>Proportion in low sexual-activity class</td>
<td>N/A</td>
<td>0.98</td>
<td>0.95</td>
<td>30, 58, 59</td>
</tr>
<tr>
<td>Proportion of daily arrestees in high sexual-activity class</td>
<td>N/A</td>
<td>0.50</td>
<td>0.50</td>
<td>59</td>
</tr>
<tr>
<td>Community annual screening coverage</td>
<td>(s)</td>
<td>0.30</td>
<td>0.10–0.5</td>
<td>35, 60</td>
</tr>
<tr>
<td>Community postscreening treatment rate</td>
<td>N/A</td>
<td>0.80</td>
<td>0.50–0.99</td>
<td>61, 62</td>
</tr>
<tr>
<td>Test sensitivity</td>
<td>N/A</td>
<td>0.85</td>
<td>0.70–1.0</td>
<td>63, 64</td>
</tr>
<tr>
<td>Treatment efficacy (doxycycline, azithromycin)</td>
<td>N/A</td>
<td>0.92</td>
<td>0.90–0.99</td>
<td>65</td>
</tr>
<tr>
<td>Jail screening coverage at intake</td>
<td>(c)</td>
<td>0.90</td>
<td>0.90</td>
<td>3a</td>
</tr>
<tr>
<td>Jail postscreening treatment rate</td>
<td>N/A</td>
<td>0.90</td>
<td>0.50–1.0</td>
<td>3a</td>
</tr>
<tr>
<td>Mixing parameter(b)</td>
<td>(\rho)</td>
<td>0.50 (0.10–0.90)c</td>
<td>Assumed</td>
<td></td>
</tr>
<tr>
<td>Relative partnership duration—low–low(d)</td>
<td>(\epsilon)</td>
<td>0.50</td>
<td>0.50</td>
<td>54, 55</td>
</tr>
</tbody>
</table>

Abbreviation: N/A, not applicable.

\(a\) Estimated from the study report.

\(b\) Equals 1 for fully assortative mixing (i.e., partners are chosen exclusively from the corresponding sexual-activity class of the opposite sex) and 0 for random mixing (i.e., partners are chosen without regard to sexual-activity class) (26).

\(c\) Numbers in parentheses, range.

\(d\) Differentiates between the relatively longer duration of partnerships formed between persons with low–low sexual activity levels versus persons with low–high and high–high sexual activity levels.

rate, program coverage, and disease burden indicated that the community prevalence decreased by 54% (from 4.6% to 2.1%) within approximately 3 years of the onset of the program (see Figure 2). The estimated impact was 57.5% for men (community prevalence decreased from 4.0% to 1.7%) and 51.0% for women (community prevalence decreased from 5.1% to 2.5%). The impact on the prevalence of infection among people in jail for the small-community analysis was a 78.9% decline (jail prevalence for both men and women decreased from 14.7% to 3.1%).

Sensitivity and uncertainty analyses

Figure 3A plots the “before and after” chlamydia prevalence rates from the 1,000 simulations (minus the 88 simulations that did not produce steady-state prevalence rates). The diagonal line shows the line of equality along which steady-state prevalence rates before and after the onset of the program were equal. The postprogram “after” prevalence is shown on the horizontal axis. Thus, points above the line indicate a decrease in chlamydia prevalence attributable to the program (i.e., the prevalence before the program exceeded the prevalence after the program), and the distance of the points above the line shows the degree of the impact. The estimated steady-state prevalence in the community before the program ranged from 0.43% to 12.11%, which is consistent with chlamydia prevalence reported in surveillance reports for different communities and subpopulations (1).

Figure 3B shows the program impact (decrease in chlamydia prevalence in the community) for all 912 simulations. In two-thirds (67%) of the simulations, the program impact was between 0% and 5%, while in slightly over 5% of the simulations the program impact was greater than 19.9%. The program impact ranged from 0.1% to 58.3%.
(mean = 5.6%, median = 2.9% (see Figure 3B insert)) across all of the simulations.

Figure 3C shows the absolute change in chlamydia prevalence in the 912 simulations. In a majority (52%) of the simulations, the absolute change in prevalence was between 0% and 0.1%. In less than 4% of the simulations, the estimated absolute change in steady-state prevalence was greater than 0.49%. Absolute change in prevalence ranged from 0.004% to 2.6% (mean = 0.2, median = 0.1 (see Figure 3C insert)) across all simulations.

Finally, Figure 3D shows the program impact when we used 80%–100% for the screening coverage and post-screening treatment rate. In over two-thirds (69%) of the simulations, the program impact was over 5%, while in almost one-fifth (19%) of the simulations, the program impact was over 19.9%. Across all simulations, the program impact ranged from 0.33% to 85.94% (mean = 13.34% (95% confidence interval: 12.37, 14.31), median = 7.93% (see Figure 3D insert)).

The PRCCs for correlation between the outcome measure (program impact) and selected model parameters are presented in Table 2 in decreasing order of influence. The signs of the PRCCs indicate the qualitative effect of the parameter on the impact (e.g., a positive sign indicates that increases in the given parameter will increase program impact). In our model, jail screening coverage was the most influential (PRCC = 0.51), followed by the incarceration rate (the size of the jail population) for men (PRCC = 0.48). Thus, the higher the jail screening coverage and the male incarceration rate, the greater the impact of the program (i.e., a larger decrease in chlamydia prevalence in the community).

DISCUSSION

Our model demonstrated that a sustained jail-based screen-and-treat program for chlamydia could potentially reduce the burden of disease in the community. Under base-case assumptions, the decrease in chlamydia prevalence attributable to jail screening was 13% in a large community and 54% in a small community with a relatively higher incarceration rate, prevalence of infection, and program coverage. For both the large- and small-community analyses, the full impact of the jail-based screen-and-treat programs took about 3 years to achieve, although most (at least 60%) of the potential impact was realized by the end of the first year. The comprehensive sensitivity and uncertainty analysis also showed that the impact on chlamydia prevalence in the community could be as high as 58%.
These results are consistent with the results reported by Barry et al. (14) and Broad et al. (24).

Based on the structure of our model, any factors that decrease the average duration of infection (such as jail-based screening) will lead to a decrease in chlamydia prevalence in the community. Therefore, the question of most interest is not whether jail-based screening will have an impact but what is the most plausible range of the estimated impact of jail-based chlamydia screening. In our sensitivity analyses, the reduction in chlamydia prevalence in the community ranged from 0.1% to 58% and was less than 5% in two-thirds of the simulations when the screening coverage ranged from 10% to 100% and the postscreening treatment rate ranged from 50% to 100%. However, when we limited the sensitivity analyses to programs with high screening coverage (80%–100%), the reduction in chlamydia prevalence in the community ranged from 0.3% to 86% and was greater than 5% in over two-thirds of the simulations.

Our results suggest that the impact might be substantially higher for jurisdictions (or subpopulations within jurisdictions) that have high incarceration rates, because persons reached by jail-based programs are likely to belong to the core group of persons with chlamydial infection in the community. Our results also suggest that for some jurisdictions (with certain characteristics), jail-based screen-and-treat programs may play an important role in achieving community goals for reducing STD burden, particularly in instances of STD outbreaks such as those that occur with syphilis. A study in Louisiana found that syphilis screening in jails appeared to have reduced substantially the prevalence of syphilis in that community (16). However, the effectiveness of a jail-based program will depend on the specific characteristics of the jurisdiction and the nature of the program.
Table 2. Partial Rank Correlation Coefficients for Select Parameters Used in a Model for Assessing the Impact of a Jail-Based Chlamydia Screening Program on a Hypothetical Community’s Chlamydia Prevalence

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PRCC*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jail screening coverage at intake</td>
<td>0.51***</td>
</tr>
<tr>
<td>Jail population (incarceration rate), men</td>
<td>0.48***</td>
</tr>
<tr>
<td>Proportion in low sexual-activity class, men</td>
<td>0.36***</td>
</tr>
<tr>
<td>Proportion of incarcerated men in high sexual-activity class</td>
<td>0.32***</td>
</tr>
<tr>
<td>Proportion in low sexual-activity class, women</td>
<td>0.23***</td>
</tr>
<tr>
<td>Per-contact transmission, female to male</td>
<td>−0.18***</td>
</tr>
<tr>
<td>Proportion of incarcerated women in high sexual-activity class</td>
<td>−0.15***</td>
</tr>
<tr>
<td>Jail postscreening treatment rate</td>
<td>0.13***</td>
</tr>
<tr>
<td>Per-contact transmission, male to female</td>
<td>−0.11***</td>
</tr>
<tr>
<td>Proportion of symptomatic infections, men</td>
<td>0.10***</td>
</tr>
<tr>
<td>No. of sex partners in past year, high sexual-activity class, women</td>
<td>−0.08***</td>
</tr>
<tr>
<td>Mixing parameter</td>
<td>−0.07***</td>
</tr>
<tr>
<td>Test sensitivity</td>
<td>0.07***</td>
</tr>
<tr>
<td>No. booked per day, men</td>
<td>0.06*</td>
</tr>
<tr>
<td>No. of sex partners in past year, high sexual-activity class, men</td>
<td>−0.05*</td>
</tr>
<tr>
<td>Proportion of symptomatic infections, women</td>
<td>0.05*</td>
</tr>
</tbody>
</table>

Abbreviation: PRCC, partial rank correlation coefficient.

* $P < 0.10$; ** $P < 0.05$; *** $P < 0.01$.

* Only parameters with $P$ values less than 0.10 are presented.

program on the community burden of infection might be substantially enhanced by including other community-based prevention and control services, such as comprehensive screening and treatment in juvenile detention centers (in communities with a high prevalence of infection in these settings (21, 38, 39)) and partner notification services (40).

Our results further suggest that, while a jail-based screen-and-treat program might have an impact on overall community prevalence of chlamydia, the impact might not be detectable through surveillance when looking at a broad community with overall low incarceration rates, because the impact is likely to be relatively small in terms of the number of cases prevented in comparison with the number of cases in the community as a whole. For example, in the large community that we modeled, with 2 million people, we assumed that 30% of women (i.e., 300,000) were already being screened annually through routine medical services. The community-level prevalence impact from jail screening we calculated was an absolute decrease of 0.3%, from 2.6% to 2.3%. Although screening 300,000 women annually through routine health services would provide a sample size with sufficient statistical power to detect the reduction from jail screening if community prevalence were otherwise stable, it could be easily missed, especially if it were concealed by trends caused by other forces not included in our model. The difficulty in assessing the impact of jail-based STD screening programs based on changes in community-level STD prevalence rates highlights the need for mathematical models (41).

The key benefit of jail-based programs, as suggested by our results, is that they provide a unique opportunity to screen and treat high-risk men (who may have limited ability and incentive to seek chlamydial screening in the community) and the underserved (the incarcerated population has poor access to medical care (42)), who are typically hard to reach for STD screening. Identifying and treating these infections thereby effectively reduces the duration of infectiousness, which is one of the major determinants of the spread of infectious diseases.

The PRCC analysis showed that the most important factor influencing the impact of a jail screening program is implementation—that is, conducting the program with high screening rates. Most of the other high-impact variables are relatively exogenous with respect to the screening program (e.g., incarceration rate, proportions of the incarcerated and nonincarcerated population in high and low sexual-activity groups). Of the other variables that can be influenced by policy-makers, the second most influential (after screening coverage, but it is substantially less influential than screening coverage) is the treatment rate among screened persons who test positive. Jail screen-and-treat programs must be carefully designed to ensure that test specimens can be processed quickly and inmates can be treated before they are released into the community, where treatment can be more difficult (43).

Limitations

The main limitation of our study is the uncertainty in the model parameters taken from the published literature. Across a range of scenarios (when all model parameters were varied simultaneously), we found that jail-based screening could reduce chlamydia prevalence in the community, although the estimated magnitude of this impact varied substantially. Additional limitations include simplifying assumptions, which are a typical characteristic of modeling. Key simplifying assumptions are detailed below. Although our model is dynamic in terms of the sizes of the groups in the different compartments, all of the parameter values were constant over the period of the analyses. For instance, the number of sex partners in the last year (a measure of sexual behavior) was assumed to be constant over the entire period of the analyses. The model allowed for sex partnerships to form among men and women of different ages (from 18 to 35 years), but for simplicity we assumed that partners were chosen independently of age and other sociodemographic characteristics such as race/ethnicity.

We ignored movements from jail to prison and from prison back into the community in this analysis, because persons who are in prison do not have contact with the community for at least 1 year (7). Additionally, given the average maximum duration of infection that we used (365 days for women and 182.5 days for men), most of the persons who were infected at the beginning of their incarceration and transferred to prison would have recovered by the time they were released from prison, at least a year later. For these reasons, excluding movements from jail to
prison in our model implied that we may have overestimated the impact of the program on the prevalence of chlamydia in the community. In addition, the higher the rate of movement from jail to prison, the lower the estimated impact on the community prevalence would be.

We assumed a short duration of infection for symptomatic cases, implying that all persons who have symptoms have access to and seek medical care, which might not be the case. Relaxing this assumption would increase the estimated impact of the program, because more infected persons would be reached through the jail program as a result of increased prevalence among symptomatic community members and arrestees.

We examined only 1 “community” and ignored entry into and exit from the community to other communities (such as adjacent towns and cities). Within the 1 hypothetical community, we assumed that people would choose their sex partners randomly from all persons in the community, subject to the mixing parameters we included. We also did not specifically examine repeat incarcerations due to recidivism in our model, as we assumed that the probability of incarceration was the same for all community members regardless of whether or not they had ever been previously incarcerated. We did not model any geographical subdivisions. In some cases, localized networks within the community could exist, where there might be limited partner selection from adjoining areas within the community (44). If the incarceration rates were higher in some geographical areas than others, as well, accounting for such heterogeneity could potentially create small areas where the impact on the nonincarcerated prevalence would be larger than in the community as a whole. Because of this potential limitation, we performed the small-community analysis with higher incarceration rates and a higher initial burden of infection.

Another limitation of our study is that we did not include persons under age 18 years in the community. Including younger age groups would have required us to include age-based mixing, which would have complicated our exploratory model. However, our model included men in the age group with the highest chlamydia rates (i.e., 18–24 years (1)), who are also the likely partners of the age group of women with the highest chlamydia rates (i.e., 15–19 years (45, 46)). Further, had we included age-specific partner mixing such that the impact of jail-based screening on persons under age 18 years was assessed, the estimated impact of jail-based screening would likely have been greater.

As described in the Appendix, the average number of days spent in jail was used as a model-simplifying parameter, besides being a meaningful input to allow time for testing and treatment of chlamydia for persons with positive test results. In practice, the percentage of inmates who stay in jail for a threshold period of time (i.e., the time required for screening and treatment) may be more meaningful than the average amount of time spent in jail. As an example, the average number of days spent in jail may be misleading if many arrestees stay for a only few days but those numbers are offset by very long pretrial periods for others.

Finally, although investigators have reported high screening and treatment rates in some large jails (3), there are potential logistical challenges in the jail system (including cost and staff limitations) which may prevent the achievement and sustenance of high screening and treatment rates that are capable of producing a noticeable health impact in the community (47).

Strengths

The key strengths of our study are as follows. First, to our knowledge, it is the only dynamic mathematical model that incorporates movements into and out of jail and sexual contacts (including disease transmission) in the community for examination of the potential impact of jail-based chlamydia screening on community prevalence. Second, we performed comprehensive sensitivity analyses to address the inherent uncertainties in the parameter values required by our model. Finally, our model provides a useful illustration of the potential impact of jail-based screen-and-treat programs, especially on small communities or subpopulations with high incarceration rates, although the magnitude of this potential impact is subject to considerable uncertainty.

Conclusions

Jail-based screen-and-treat programs might play an important role in reducing the chlamydia burden in communities with a high burden of STDs (and high incarceration rates) and should be considered as part of STD prevention and control efforts where possible. In addition, jail-based screen-and-treat programs provide a key opportunity to provide preventive care and treatment to underserved populations (especially men) who have limited or no access to health care. Additional epidemiologic and modeling studies are needed to determine the optimal use of jail-based screen-and-treat programs as part of an overall STD prevention strategy.

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REFERENCES


### APPENDIX

#### Model Equations

Community equations:

\[
\frac{dx_{ijk}}{dt} = -\gamma_{ijk}x_{ijk} + \psi_{Nijk} - \phi_{Nijk} + \alpha_{i}(Z_{ijk} + Y_{ijk}) \\
+ \theta_{Xijk} + s_{i}(Z_{ijk} + Y_{ijk}) - \mu_{ijk}X_{ijk} \\
\]

\[
\frac{de_{ijk}}{dt} = \gamma_{ijk}x_{ijk} - \omega_{Eijk} - \phi_{Eijk} + \theta_{Eijk} - \mu_{ijk}E_{ijk} \\
\]

\[
\frac{dy_{ijk}}{dt} = \xi_{i}c_{ijk} - \alpha_{i}Y_{ijk} - \psi_{Yijk} - s_{i}Y_{ijk} + \theta_{Yijk} - \mu_{ijk}Y_{ijk} \\
\]

\[
\frac{dz_{ijk}}{dt} = (1 - \xi_{i})c_{ijk} - \alpha_{i}Z_{ijk} - \psi_{Zijk} - s_{i}Z_{ijk} + \theta_{Zijk} - \mu_{ijk}Z_{ijk} \\
\]

Jail equations:
\[
\frac{d}{dt}X_{ijk} = \alpha_{i}(Z_{ijk} + Y_{ijk}) - \theta X_{ijk} + \mu_{ijk}X_{ijk} \times C(\mu_{ijk}Y_{ijk} + \mu_{ijk}Z_{ijk})
\]
\[
\frac{d}{dt}E_{ijk} = -\omega E_{ijk} - \theta E_{ijk} + \mu_{ijk}E_{ijk}
\]
\[
\frac{d}{dt}Y_{ijk} = \xi_{ij}\omega E_{ijk} - \alpha_{i}Y_{ijk} - \theta Y_{ijk} + (1 - C)\mu_{ijk}Y_{ijk}
\]
\[
\frac{d}{dt}Z_{ijk} = (1 - \xi_{ij})\omega E_{ijk} - \alpha_{i}Z_{ijk} - \theta Z_{ijk} + (1 - C)\mu_{ijk}Z_{ijk}
\]

Force of infection:
\[
\gamma_{ijk} = \beta_{ij}c_{ijk}(\tau_{ijk}k_{rjk} + \tau_{ijk}k_{rj'k'})
\]

Population size:
\[
N_{ijk} = X_{ijk} + E_{ijk} + Y_{ijk} + Z_{ijk}
\]

Prevalence:
\[
\kappa_{ijk} = \frac{Y_{ijk} + Z_{ijk}}{N_{ijk}}
\]

Mixing equation:
\[
\tau_{ijk} = \varepsilon M_{jk} + (1 - \varepsilon)\left(\frac{c_{ijk}N_{ijk}}{c_{ijk}N_{ijk} + c_{ijk}k_{rjk}N_{ijk}}\right)
\]

In the above equations, \(X\) (susceptible), \(E\) (exposed), \(Y\) (infectious and symptomatic), and \(Z\) (infectious and asymptomatic) are the 4 compartments representing 4 mutually exclusive chlamydia health statuses; the subscripts \(i\), \(j\), and \(k\) represent gender (\(i = 1\) for men, \(i = 2\) for women), sexual-activity class (\(j = 1\) for low, \(j = 2\) for high), and location (\(k = 1\) for community, \(k = 2\) for jail), respectively, unless otherwise noted; the rate of exit and entry into the community population per day (\(\varphi\)) is 0.05/365 (0.05 per year); the recovery rate is represented by \(\alpha_{i}\) (the subscript represents symptomatic and asymptomatic infections); community and jail screen-and-treat coverage are represented by \(s_{j}\) (women only) and \(C\) (a product of the screening rate, test sensitivity, postscreening treatment rate, and treatment efficacy); the proportion of symptomatic infections is \(\xi_{i}\); the rate of exit from the exposed state to the infectious states is \(\omega\) (for simplicity, we assumed that the time from infection to infectiousness was the same as the time from infection to symptoms); the rate of exit from jail is represented by \(\theta\); the per capita probability of going to jail is \(\mu_{ijk}\) (\(u_{ijk}/N_{ijk}\), where \(u\) is the average number of arrestees per day); an opposite location/subpopulation is differentiated by \(\ast\); the force of infection \(\gamma_{ijk}\) is given by the product of the per-contact transmission probability \(\beta_{ij}\), the rate of sex-partner change \(c_{ijk}\), and the proportion of sex partners infected—determined by the mixing matrix \(\tau_{ijk}\) and the prevalence in the associated sexual-activity classes \(\kappa_{ijk}\); and \(\rho_{ij}\) allows low–low partnerships to last longer (1 for high–low/low–high and 2 for low–low). \(M_{jk}\) represents full assortative mixing (1 when \(j = k\) and 0 when \(j \neq k\)). Thus, when \(\varepsilon = 0\), mixing is random and when \(\varepsilon = 1\), mixing is fully assortative (30). Partnerships in the community were balanced by adjusting the partnership rates using the relationships \(c_{11}N_{11} = c_{21}N_{21}\) and \(c_{12}N_{12} = c_{22}N_{22}\) (30, 48). Owing to a lack of data on sexually transmitted disease transmission in jails (49), we assumed that there was no transmission in jail. That is, in the jail setting, the force of infection \(\gamma_{ijk}\) is assumed to be 0, and thus it is not included in the jail equations.

The population for the two locations remained constant \(N_{ijk} = X_{ijk} + E_{ijk} + Y_{ijk} + Z_{ijk}\), such that the population in jail was represented by the relationship \(N_{ijk} = u_{ijk}/\theta\) (50). Thus, for the sensitivity and uncertainty analyses on \(u\), \(1/\theta\) was varied to keep \(\mathcal{N}\) constant, and the results of the sensitivity on \(u\) and \(1/\theta\) were similar. This explains why we did not show the results for \(1/\theta\).