Effect of Screening and Treatment for Gonorrhea and Chlamydia on HIV Incidence Among Men Who Have Sex With Men in the United States: A Modeling Analysis

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Background: Previous models have estimated the total population attributable fraction of *Neisseria gonorrhoeae* and *Chlamydia trachomatis* (NG/CT) on HIV incidence among men who have sex with men (MSM), but this does not represent realistic intervention effects. We estimated the potential impact of screening for NG/CT on downstream incidence of HIV among MSM.

Methods: Using a network model, we estimated the effects of varying coverage levels for sexually transmitted infection screening among different priority populations: all sexually active MSM regardless of HIV serostatus, MSM with multiple recent (past 6 months) sex partners regardless of serostatus, MSM without HIV, and MSM with HIV. Under the assumption that all screening events included a urethral test, we also examined the effect of increasing the proportion of screening events that include rectal screening for NG/CT on HIV incidence.

Results: Increasing annual NG/CT screening among sexually active MSM by 60% averted 4.9% of HIV infections over a 10-year period (interquartile range, 2.8%–6.8%). More HIV infections were averted when screening was focused on MSM with multiple recent sex partners: 60% coverage among MSM with multiple recent sex partners averted 9.8% of HIV infections (interquartile range, 8.1%–11.6%). Increased sexually transmitted infection screening among MSM without HIV averted more new HIV infections compared with the transmissions averted because of screening MSM with HIV, but fewer NG/CT tests were needed among MSM with HIV to avert a single new HIV infection.

Conclusions: Screening of NG/CT among MSM is expected to lead to modest but clinically relevant reductions in HIV incidence among MSM.

Neisseria gonorrhoeae and *Chlamydia trachomatis* (hereafter, NG/CT) are highly prevalent sexually transmitted infections (STIs) among men who have sex with men (MSM) in the United States.[1] *Neisseria gonorrhoeae*/*Chlamydia trachomatis* and HIV share common modes of transmission, and NG/CT infection increases susceptibility to and transmissability of HIV in HIV serodiscordant sexual partnerships.[2,3] Among men living with HIV, NG/CT coinfection can increase the probability of onward transmission of HIV by increasing viral shedding.[4] Among men at risk of HIV, NG/CT infection can increase susceptibility to HIV by compromising the rectal or urethral epithelium and by increasing the concentration of HIV target cells in the genital or urethral tract.[4] Among men, from 2015 to 2019, rates of chlamydia diagnoses increased by 32% and gonorrhea diagnoses increased by 61%.[1] A recent report found that gonorrhea diagnoses among men living with diagnosed HIV increased by 61% from 2010 to 2019.[5] Urogenital gonorrhea is more prevalent among MSM with HIV compared with MSM without HIV; no differences were observed in urogenital chlamydia prevalence based on HIV status.[1]

Screening programs designed to detect and treat NG/CT are a critical component of the public health response to these infections. Currently, the US Centers for Disease Control and Prevention recommends that sexually active MSM receive NG/CT screening at all anatomic sites of sexual activity at least annually.[6] Estimates of how well these guidelines are followed in clinical settings are difficult to obtain because there is not a central data repository describing all STI screenings. In a large national survey of sexually active MSM, only 42% reported receiving any STI test, and only 16% had received any extragenital STI test in the past 12 months.[7] Of those reporting extragenital screening, 87% received throat swabs and 82% received rectal swabs. Screening is particularly important because most rectal NG/CT infections are asymptomatic[8,9] and will not be detected based on syndromic management alone.

The overlapping modes of transmission and biological synergy between HIV and STIs led to several trials to test the effectiveness of STI screening programs to reduce HIV incidence, the results of which have been summarized previously.[2,10,11] Briefly, only one trial[12] has demonstrated reductions in HIV incidence after a community-level intervention to detect and treat STIs. A number of hypotheses have been put forward for the lack of effect in these trials,[10] including enhanced STI prevention in control groups that likely diluted any intervention effect. Differences in stage of the HIV epidemic might have also played a role in these disparate trial results. Notably, all of these trials were conducted among the general population; the effectiveness of STI screening and treatment to reduce HIV incidence among MSM remains unclear. HIV is transmitted more efficiently via anal sex compared with vaginal sex,[13,14] so the effect of increased STI screening might have a more pronounced effect on HIV incidence among MSM.

Previously, we estimated the population attributable fraction of urethral and rectal NG/CT on HIV incidence among MSM to be approximately 10%[15]; another study has estimated this value to be 15% among young MSM.[16] The population attributable fraction is the proportion of HIV incidence that could be averted if NG/CT were to be eliminated from the population. Although useful, it does

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not provide a direct estimate of the proportion of new infections of HIV that might be averted because of realistic screening and treatment programs that reduce, but do not eliminate, NG/CT. The goal of this analysis is to estimate the effect of realistic increases in NG/CT screening overall, focusing on increases by HIV serostatus and risk group, and increasing rectal screening on HIV incidence among MSM.

METHODS

We used an open-source, network-based model of HIV, NG, and CT transmission dynamics for a population of MSM in Atlanta, Georgia, built with the *EpiModel* software platform,[17] to assess the effect of NG/CT screening on HIV incidence. We modeled the transmission of HIV, NG, and CT among sexually active Black, Hispanic, and White MSM aged 15 to 64 years. Dynamic contact networks were fit using temporal exponential random graph models[18] to data from the ARTnet Study, an egocentric network study of MSM partnerships in the United States.[19] The model has previously been adapted to estimate the contribution of NG/CT on HIV incidence among this population[15] and the effect of different levels of NG/CT screening on NG/CT incidence.[20] This model accounts for partnership formation and dissolution; sexual activity within partnerships; transmission and disease progression of HIV, NG, and CT; and screening and treatment of HIV, NG, and CT. Key parameters are described hereinafter and presented in Table 1; additional details describing each of these processes are included in the Technical Appendix, http://links.lww.com/OLQ/A852.

HIV/STI Transmission and Disease Progression

HIV transmission occurs stochastically in sexual episodes between HIV serodiscordant partners, with a probability modified by condom use, preexposure prophylaxis (PrEP) use, circumcision status of the insertive partner, and the HIV treatment status and viral load of the HIV-infected partner. HIV transmission and acquisition probabilities are further modified by prevalent NG/CT in either partner (see discussion hereinafter). After acquisition, HIV disease progresses through acute, chronic, and AIDS stages dependent on treatment initiation and adherence (see sections 6 and 7 of the Technical Appendix, http://links.lww.com/OLQ/A852).

Transmission of NG/CT occurs stochastically in sexual episodes between STI-discordant partners based on sexual position and anatomical site of infection. *Neisseria gonorrhoeae*/*Chlamydia trachomatis* can occur at genital and rectal sites (pharyngeal infections are not modeled, nor is oral sex), and infection persists until treatment or spontaneous recovery. Further details on NG/CT transmission and recovery are provided in the Technical Appendix, http://links.lww.com/OLQ/A852.

Effect of NG/CT on HIV Transmission and Acquisition

The effects of NG/CT on HIV transmission and acquisition risk were dependent on the anatomical site of NG/CT infection and directional based on sexual role during anal intercourse. That is, only urethral NG/CT would affect HIV transmission or acquisition risk in the insertive partner and only rectal NG/CT would affect HIV transmission or acquisition risk in the receptive partner. Informed by empirical studies,[21–24] we used our model to estimate the relative increase in HIV acquisition risk given current urethral and rectal NG/CT infection. The odds of HIV acquisition for a receptive partner in the presence of rectal NG/CT were increased by 178% (odds ratio [OR], 2.78). The odds of HIV acquisition for an insertive partner with urethral NG/CT were increased by 73% (OR, 1.73). Data estimating the effect of rectal and urethral NG/CT infection on the risk of onward HIV transmission were more limited. As we have done previously,[15] we assumed that prevalent NG/CT in a partner with HIV increased the risk of transmission to a partner without HIV by 30% (OR, 1.3), based on data from a cohort of heterosexually active adults in Zambia.[25]

TABLE 1. Key Parameters for the Base Case Scenario of the Model

Parameter	Value
Probability of HIV transmission, receptive anal sex	0.008938 base probability when HIV+ partner has 4.5 $\log_{10}$ viral load
Probability of HIV transmission, insertive anal sex	0.003379 base probability when HIV+ partner has 4.5 $\log_{10}$ viral load
Multipliers of HIV transmission probabilities	
HIV+ partner not virally suppressed or not on ART	Multiplier of $2.45^{(VL\ -\ 4.5)}$ on sexual role–specific base probabilities above
HIV+ partner virally suppressed and on ART	0.000022 base probability, regardless of sexual role
HIV+ partner in acute HIV stage	Multiplier of 6
Condom use	Multiplier of 0.05
Circumcision status of HIV− partner if insertive	Multiplier of 0.40
PrEP use by HIV− partner	High adherence: multiplier of 0.01 Medium adherence: multiplier of 0.19 Low adherence: multiplier of 0.69
Urethral gonococcal or chlamydial infection	Multiplier of 1.73 for HIV acquisition Multiplier of 1.30 for HIV transmission
Rectal gonococcal or chlamydial infection	Multiplier of 2.78 for HIV acquisition Multiplier of 1.30 for HIV transmission
Probability of infection being symptomatic	
Chlamydia, rectal	0.14
Chlamydia, urethral	0.48
Gonorrhea, rectal	0.16
Gonorrhea, urethral	0.80
Base case asymptomatic STI screening probabilities	
MSM with HIV, rectal screening	0.38
MSM with HIV, urethral screening	0.61
MSM without HIV, rectal screening	0.21
MSM without HIV, urethral screening	0.44

Additional parameters, derivations, and sources are presented in the Technical Appendix, http://links.lww.com/OLQ/A852.

NG/CT Screening and Treatment

In the base (calibrated) model, men were stochastically screened for NG and CT, with rates reflecting the past-year prevalence of HIV serostatus–specific NG and CT screening, informed by the National HIV Behavioral Surveillance System.[26] In the base model, this resulted in at least 1 NG/CT screening event for 44% of MSM without HIV and 61% of MSM with HIV over a 12-month period. All screening events were assumed to include urethral screening, and a subset of these events were assumed to also include rectal screening. Based on data from the American Men's Internet Survey, 48% and 63% of urogenital NG/CT screening events also included rectal screening among MSM without HIV and MSM with HIV, respectively.[7] Overall and rectal-specific coverage levels were varied across scenarios (described in more detail hereinafter) to assess the effect of higher levels of NG/CT screening on HIV incidence. The prevalence of HIV PrEP use was assumed to be 15%.[27] Preexposure prophylaxis–using men received STI screening every 6 months as part of regular PrEP visits and were not affected by the general increases in NG/CT screening coverage.[28]

The causal effect of NG/CT screening on HIV incidence is mediated through detection and successful treatment of prevalent NG/CT infections. To account for delays in treatment initiation and possible loss to follow-up, men with a positive screening test result had an 80% weekly probability of initiating treatment, resulting in >99% treatment coverage within 3 weeks of detection assuming that treatment is geometrically distributed. To account for delays in care seeking,[29,30] men with symptomatic infection had a 70% weekly probability of diagnosis and treatment, resulting in >99% treatment within 4 weeks of symptoms. Treatment was assumed to be 100% effective in the week it was administered.

Model Scenarios

Each scenario was simulated 1000 times in weekly timesteps for 10 years. Model scenarios were designed to estimate the effect of increasing coverage of NG/CT screening overall and the effect of differential increases in coverage of urethral and rectal NG/CT screening by HIV serostatus. In the first scenarios, we separately assessed the effect of increased coverage of NG/CT screening among all sexually active men and only among men with multiple recent (past 6 months) partners, regardless of HIV serostatus. The Sexually Transmitted Diseases Treatment Guidelines recommend more frequent sexually transmitted diseases testing for MSM who have multiple recent partners,[6] which we defined as having 2+ partners in the past 6 months, as has been done previously.[20] In these scenarios, MSM with multiple recent partners screened biannually instead of annually. Next, leaving NG/CT screening coverage for MSM with HIV at base scenario levels, we assessed the effect of increasing coverage of NG/CT screening among MSM without HIV only. Within each level of screening coverage, we also assessed varying the proportion (base proportion, 70%–100%) of screening events that included a rectal test. This same process was repeated for MSM with HIV, leaving coverage of NG/CT screening at base levels for MSM without HIV.

Analytic Outcomes

To estimate the effect of NG/CT screening on HIV incidence, we estimated the proportion of HIV infections averted and number of NG/CT tests needed per HIV infection averted comparing scenarios in which screening coverage was increased to the base scenario (current estimated screening levels). Proportion of HIV infections averted was the proportion of incident HIV infections prevented in a given scenario compared with the base scenario. Number of tests per infection averted was the number of NG/CT screening tests needed to avert a single infection of HIV and is calculated as the number of additional NG/CT tests in a scenario compared with the base scenario divided by the number of HIV infections averted in that scenario compared with the base scenario. This quantity is only meaningful in scenarios in which HIV infections are averted compared with the base scenario, so we restricted calculation of the number of additional NG/CT tests per HIV infection averted to these scenarios. To provide context, we report the proportion of simulations in which the number of HIV infections averted is greater than zero for each scenario. We also report HIV incidence per 100 person-years in the final year of each scenario. Median and interquartile range (IQR) across the 1000 simulations in each scenario are reported for each measure.

RESULTS

In the base scenario, HIV incidence was 1.27 (IQR, 1.20–1.33) per 100 person-years (Table 2). Increasing coverage of NG/CT screening among all sexually active MSM had a modest effect on HIV incidence. A 60% relative increase in the percentage of MSM screened for NG/CT at least once per year would avert 4.9% (IQR, 2.8%–6.8%) of HIV infections for 10 years compared with current estimated screening coverage in the base scenario. Implementing biannual NG/CT screening among MSM with multiple recent partners had a larger impact; when 60% of MSM with multiple recent partners screened for NG/CT biannually, 9.8% (IQR, 8.1%–11.6%) of HIV infections were averted compared with the base scenario. In all scenarios of increased screening among men with multiple partners in the past 6 months, more than 99% of simulations resulted in the number of HIV infections averted being greater than zero.

We conducted scenarios to isolate the relative effects of increasing urethral versus rectal NG/CT screening. Increasing urethral screening among MSM without HIV resulted in successively larger percentages of HIV infections averted (Table 3). Within each level of increased urethral screening coverage, increases in the proportion of screening events that included rectal screening resulted in larger percentages of HIV infections averted. With no change in the baseline proportion of screening events that included a rectal screen, a 60% increase in urethral screening among MSM without HIV would avert 2.5% (IQR, 0.5%–4.3%) of HIV infections; if all urethral screening events included a rectal screen, the same increase in urethral screening would avert 3.9% (IQR, 1.6%–5.9%) of HIV infections. If rectal screening remained at current coverage levels, one HIV infection would be averted for every 2117 (IQR, 1297–3512) additional NG/CT tests conducted among MSM without HIV. If all urethral screening events included a rectal screen, 1 HIV infection would be averted for every 2310 (IQR, 1625–4221) additional NG/CT tests conducted among MSM without HIV. In these scenarios with a 60% increase in screening among men without HIV, between 80.2% and 90.7% of simulations resulted in averting HIV infections compared with the base scenario, depending on the proportion of screening events that included rectal screening.

Smaller effects on HIV incidence resulted from increases in NG/CT screening among MSM with HIV (Table 4). A 60% increase in NG/CT screening among MSM with HIV with no increase in the proportion of screening events that include a rectal screen would avert 0.8% (IQR, −1.3% to 2.7%) of HIV infections for 10 years; if all screening events included a rectal screen, the same increase in urethral screening would avert 1.3% (IQR, −0.6% to 3.3%) of HIV infections. In scenarios with a 60% increase in NG/CT screening among MSM with HIV, when rectal screening coverage remained at baseline levels, 745 additional NG/CT tests conducted among MSM with HIV (IQR, 433 to 1472) would avert 1 new HIV infection. If rectal screens occurred

TABLE 2. HIV, Gonorrhea, and Chlamydia Incidence Per 100 Person-Years in the Last Year of Follow-up and Proportion of HIV Infections Averted and Number of Gonorrhea and Chlamydia Tests Needed to Prevent 1 HIV Infection for 10 Years of Follow-up in an Agent-Based Model of MSM in the United States

	Incidence Per 100 Person-Years					
	HIV	Gonorrhea	Chlamydia	Percent of HIV Infections Averted	No. Additional Gonorrhea and Chlamydia Tests Compared With Base Scenario Per HIV Infection Averted*	Proportion of Simulations With Number of HIV Infections Averted >0, %
Model scenario						
Base model (baseline SA coverage)	1.27 (1.20 to 1.33)	13.12 (11.46 to 14.69)	11.59 (10.78 to 12.55)	—	—	—
SA screening coverage†						
10% increase	1.26 (1.19 to 1.32)	12.56 (10.92 to 14.17)	11.03 (10.13 to 11.89)	0.44 (−1.40 to 2.57)	504 (285 to 1098)	56.2
20% increase	1.25 (1.19 to 1.31)	12.19 (10.46 to 13.84)	10.58 (9.78 to 11.45)	1.10 (−1.12 to 3.18)	859 (553 to 1853)	64.4
30% increase	1.24 (1.18 to 1.31)	11.78 (10.14 to 13.40)	10.15 (9.36 to 10.94)	1.32 (−0.65 to 3.33)	1287 (812 to 2543)	66.5
40% increase	1.24 (1.17 to 1.31)	11.67 (10.02 to 13.17)	9.76 (8.94 to 10.62)	1.39 (−0.61 to 3.59)	1650 (981 to 3527)	68.1
50% increase	1.20 (1.14 to 1.26)	10.52 (8.98 to 11.96)	8.96 (8.05 to 9.77)	4.65 (2.23 to 6.57)	1134 (818 to 1989)	92.1
60% increase	1.19 (1.13 to 1.26)	10.37 (8.52 to 11.89)	8.39 (7.65 to 9.20)	4.86 (2.81 to 6.84)	1303 (957 to 1962)	92.9
Screening coverage among MSM with ≥2 partners in past 6 months (baseline SA coverage)						
10%	1.15 (1.09 to 1.21)	8.48 (7.26 to 9.95)	4.82 (4.24 to 5.46)	7.08 (5.38 to 9.04)	2058 (1511 to 2658)	99.2
20%	1.11 (1.05 to 1.17)	6.62 (5.43 to 7.87)	2.44 (2.01 to 2.98)	9.31 (7.52 to 11.28)	2270 (1878 to 2814)	100.0
30%	1.12 (1.07 to 1.19)	5.95 (4.66 to 7.37)	1.43 (1.10 to 1.82)	8.36 (6.64 to 10.06)	3044 (2523 to 3838)	99.8
40%	1.12 (1.07 to 1.17)	5.23 (4.05 to 6.53)	0.86 (0.61 to 1.13)	8.87 (7.35 to 10.87)	3220 (2632 to 3894)	100.0
50%	1.11 (1.05 to 1.17)	4.59 (3.45 to 5.89)	0.53 (0.34 to 0.74)	9.78 (7.96 to 11.48)	3170 (2701 to 3895)	100.0
60%	1.11 (1.05 to 1.17)	4.33 (3.15 to 5.51)	0.38 (0.22 to 0.58)	9.82 (8.06 to 11.58)	3348 (2833 to 4082)	100.0

*Calculations in this column are based only on simulations in which the number of HIV infections averted was >0.

†These scenarios did not include biannual screening of MSM with multiple recent partners.

SA indicates sexually active.

TABLE 3. Effect of Increased Gonorrhea and Chlamydia Screening Among MSM Without HIV on HIV, Gonorrhea, and Chlamydia Incidence; Proportion of HIV Infections Averted; and Number of Gonorrhea and Chlamydia Tests Needed to Prevent 1 HIV Infection for 10 Years of Follow-up in an Agent-Based Model of MSM in the United States

Increase in Urethral Screening Coverage	Percent of Events That Include Rectal Test	Incidence Per 100 Person-Years			Percent of HIV Infections Averted	No. Additional Gonorrhea and Chlamydia Tests Compared With Base Scenario Per HIV Infection Averted*	Proportion of Simulations With Number of HIV Infections Averted >0, %
		HIV	Gonorrhea	Chlamydia			
0%	48	1.26 (1.21 to 1.33)	13.14 (11.41 to 14.87)	11.66 (10.68 to 12.54)	—	—	—
0%	70	1.25 (1.18 to 1.32)	12.26 (10.68 to 13.78)	10.82 (10.01 to 11.70)	0.66 (−1.44 to 2.59)	590 (322 to 1175)	59.4
0%	80	1.25 (1.18 to 1.31)	11.64 (10.01 to 13.27)	10.51 (9.75 to 11.43)	0.86 (−1.14 to 2.93)	776 (476 to 1749)	62.7
0%	90	1.24 (1.18 to 1.30)	11.22 (9.59 to 12.73)	10.18 (9.30 to 11.01)	1.24 (−0.80 to 3.27)	978 (584 to 1953)	67.1
0%	100	1.23 (1.17 to 1.30)	10.82 (9.30 to 12.43)	9.94 (9.12 to 10.83)	1.42 (−0.66 to 3.58)	1039 (672 to 2084)	66.6
10%	48	1.26 (1.19 to 1.33)	12.30 (10.74 to 14.00)	10.77 (9.88 to 11.64)	0.66 (−1.47 to 2.69)	765 (473 to 1511)	59.2
10%	70	1.25 (1.18 to 1.31)	11.69 (10.31 to 13.32)	10.51 (9.64 to 11.34)	1.17 (−1.07 to 3.30)	828 (544 to 1668)	63.7
10%	80	1.24 (1.18 to 1.30)	11.35 (9.81 to 12.97)	10.20 (9.28 to 11.02)	1.15 (−0.73 to 3.21)	1128 (696 to 2420)	66.0
10%	90	1.24 (1.18 to 1.30)	10.77 (9.25 to 12.49)	9.75 (8.93 to 10.60)	1.69 (−0.25 to 3.81)	1219 (767 to 2541)	72.4
10%	100	1.23 (1.16 to 1.29)	10.47 (8.95 to 12.11)	9.49 (8.63 to 10.31)	2.05 (−0.19 to 4.13)	1325 (879 to 2577)	72.9
20%	48	1.25 (1.18 to 1.31)	11.71 (10.19 to 13.62)	10.25 (9.42 to 11.16)	0.97 (−1.03 to 2.86)	1138 (711 to 2274)	62.8
20%	70	1.24 (1.17 to 1.31)	11.49 (9.95 to 13.12)	10.08 (9.31 to 10.92)	1.34 (−0.74 to 3.58)	1213 (723 to 2337)	66.6
20%	80	1.23 (1.17 to 1.29)	10.95 (9.43 to 12.51)	9.70 (8.89 to 10.49)	1.51 (−0.43 to 3.37)	1505 (936 to 2957)	70.7
20%	90	1.23 (1.17 to 1.29)	10.42 (8.93 to 12.13)	9.31 (8.48 to 10.18)	1.91 (−0.23 to 4.05)	1479 (953 to 2900)	72.9
20%	100	1.22 (1.16 to 1.29)	10.06 (8.47 to 11.54)	9.10 (8.19 to 9.97)	2.32 (0.25 to 4.32)	1600 (1083 to 3046)	76.9
30%	48	1.24 (1.18 to 1.31)	11.25 (9.65 to 12.89)	9.86 (9.08 to 10.65)	1.51 (−0.56 to 3.47)	1371 (891 to 2626)	68.6
30%	70	1.24 (1.17 to 1.29)	10.94 (9.37 to 12.68)	9.57 (8.76 to 10.44)	1.71 (−0.32 to 3.71)	1502 (937 to 2882)	71.9
30%	80	1.22 (1.16 to 1.28)	10.60 (8.91 to 12.07)	9.24 (8.40 to 10.07)	2.05 (−0.08 to 4.18)	1560 (1025 to 3238)	74.0
30%	90	1.22 (1.16 to 1.29)	10.18 (8.50 to 11.78)	8.98 (8.09 to 9.76)	2.49 (0.29 to 4.52)	1745 (1130 to 3212)	77.9
30%	100	1.22 (1.16 to 1.28)	9.65 (7.96 to 11.22)	8.62 (7.80 to 9.53)	2.80 (0.76 to 4.83)	1853 (1228 to 3594)	82.6
40%	48	1.23 (1.17 to 1.30)	11.07 (9.61 to 12.62)	9.58 (8.73 to 10.44)	1.81 (−0.19 to 3.78)	1660 (1052 to 3138)	72.6
40%	70	1.23 (1.16 to 1.29)	10.73 (9.18 to 12.24)	9.23 (8.44 to 10.01)	1.90 (0.12 to 4.15)	1717 (1124 to 3312)	75.8
40%	80	1.22 (1.17 to 1.28)	10.23 (8.60 to 11.72)	8.87 (8.06 to 9.66)	2.46 (0.25 to 4.29)	1870 (1266 to 3380)	77.9
40%	90	1.21 (1.15 to 1.28)	9.50 (8.18 to 11.16)	8.44 (7.71 to 9.30)	2.76 (0.53 to 4.93)	1921 (1282 to 3369)	79.8
40%	100	1.21 (1.14 to 1.27)	9.30 (7.82 to 10.80)	8.27 (7.40 to 9.02)	2.93 (1.00 to 5.07)	2090 (1396 to 3770)	84.7
50%	48	1.22 (1.16 to 1.29)	10.64 (9.25 to 12.35)	9.20 (8.35 to 10.01)	2.19 (0.14 to 4.18)	1768 (1186 to 3458)	76.6
50%	70	1.22 (1.16 to 1.28)	10.29 (8.81 to 11.78)	8.81 (8.02 to 9.65)	2.44 (0.25 to 4.43)	1879 (1239 to 3500)	77.4
50%	80	1.22 (1.16 to 1.28)	9.74 (8.18 to 11.37)	8.46 (7.63 to 9.21)	2.64 (0.66 to 4.79)	2079 (1354 to 4012)	82.1
50%	90	1.21 (1.15 to 1.27)	9.19 (7.85 to 10.92)	8.11 (7.32 to 8.92)	3.07 (1.07 to 5.07)	2186 (1453 to 3814)	84.2
50%	100	1.20 (1.13 to 1.26)	8.74 (7.35 to 10.38)	7.76 (6.99 to 8.41)	3.51 (1.54 to 5.47)	2245 (1515 to 3846)	88.5
60%	48	1.22 (1.16 to 1.28)	10.54 (8.92 to 12.13)	8.78 (8.00 to 9.59)	2.46 (0.49 to 4.32)	2117 (1297 to 3512)	80.2
60%	70	1.21 (1.15 to 1.28)	9.97 (8.47 to 11.67)	8.55 (7.77 to 9.33)	2.68 (0.59 to 4.66)	2097 (1400 to 3738)	79.5
60%	80	1.21 (1.15 to 1.27)	9.40 (7.96 to 10.88)	8.03 (7.31 to 8.88)	3.10 (1.00 to 5.00)	2203 (1531 to 4040)	84.5
60%	90	1.20 (1.14 to 1.26)	9.10 (7.55 to 10.58)	7.73 (7.00 to 8.56)	3.30 (1.26 to 5.27)	2375 (1607 to 4079)	85.7
60%	100	1.19 (1.13 to 1.26)	8.34 (6.99 to 9.79)	7.31 (6.62 to 8.14)	3.85 (1.64 to 5.89)	2310 (1625 to 4221)	90.7

*Calculations in this column are based only on simulations in which the number of HIV infections averted was >0.

TABLE 4. Effect of Increased Gonorrhea and Chlamydia Screening Among MSM With HIV on HIV, Gonorrhea, and Chlamydia Incidence; Proportion of HIV Infections Averted; and Number of Gonorrhea and Chlamydia Tests Needed to Prevent 1 HIV Infection for 10 Years of Follow-up in an Agent-Based Model of MSM in the United States

Increase in Urethral Screening Coverage	Percent of Events That Include Rectal Test	Incidence Per 100 Person-Years			Percent of HIV Infections Averted	No. Additional Gonorrhea and Chlamydia Tests Compared With Base Scenario Per HIV Infection Averted*	Proportion of Simulations With Number of HIV Infections Averted >0, %
		HIV	Gonorrhea	Chlamydia			
0%	63	1.27 (1.21 to 1.34)	13.25 (11.65 to 14.91)	11.62 (10.75 to 12.59)	—	—	
0%	70	1.27 (1.20 to 1.33)	13.20 (11.44 to 14.99)	11.57 (10.72 to 12.48)	0.07 (−2.08 to 2.25)	50 (28 to 107)	50.9
0%	80	1.26 (1.19 to 1.33)	12.82 (11.22 to 14.53)	11.38 (10.57 to 12.29)	0.30 (−1.85 to 2.22)	133 (74 to 279)	54.0
0%	90	1.27 (1.20 to 1.33)	12.70 (11.08 to 14.30)	11.35 (10.48 to 12.19)	0.29 (−1.71 to 2.32)	198 (121 to 391)	53.2
0%	100	1.26 (1.19 to 1.32)	12.33 (10.67 to 14.11)	11.20 (10.31 to 12.13)	0.63 (−1.61 to 2.56)	280 (163 to 581)	57.6
10%	63	1.27 (1.20 to 1.33)	13.08 (11.47 to 14.60)	11.52 (10.63 to 12.33)	0.02 (−1.91 to 2.12)	136 (80 to 273)	50.2
10%	70	1.27 (1.20 to 1.34)	12.90 (11.31 to 14.56)	11.42 (10.56 to 12.25)	0.12 (−1.91 to 2.25)	181 (108 to 376)	51.4
10%	80	1.26 (1.20 to 1.32)	12.68 (11.08 to 14.34)	11.25 (10.42 to 12.07)	0.29 (−1.74 to 2.25)	280 (168 to 554)	53.9
10%	90	1.26 (1.20 to 1.33)	12.49 (10.76 to 14.28)	11.04 (10.09 to 11.98)	0.39 (−1.72 to 2.49)	342 (204 to 762)	55.4
10%	100	1.25 (1.19 to 1.33)	12.22 (10.68 to 13.86)	10.97 (10.14 to 11.89)	0.52 (−1.64 to 2.40)	437 (270 to 851)	56.2
20%	63	1.26 (1.20 to 1.32)	12.69 (11.20 to 14.49)	11.26 (10.37 to 12.21)	0.32 (−1.81 to 2.56)	250 (147 to 568)	54.3
20%	70	1.26 (1.19 to 1.33)	12.71 (11.02 to 14.20)	11.15 (10.23 to 12.06)	0.32 (−1.81 to 2.49)	309 (191 to 698)	53.8
20%	80	1.26 (1.20 to 1.33)	12.40 (10.83 to 14.11)	11.02 (10.21 to 11.88)	0.56 (−1.52 to 2.62)	404 (236 to 839)	57.7
20%	90	1.25 (1.19 to 1.32)	12.37 (10.81 to 13.86)	11.01 (10.16 to 11.93)	0.58 (−1.44 to 2.73)	466 (268 to 930)	56.7
20%	100	1.25 (1.19 to 1.32)	12.21 (10.70 to 14.02)	10.80 (9.90 to 11.71)	0.59 (−1.37 to 2.76)	529 (335 to 1098)	57.4
30%	63	1.26 (1.20 to 1.32)	12.64 (11.05 to 14.19)	11.12 (10.26 to 12.00)	0.44 (−1.68 to 2.73)	359 (224 to 820)	56.2
30%	70	1.26 (1.19 to 1.32)	12.65 (10.88 to 14.24)	11.13 (10.27 to 11.98)	0.32 (−1.81 to 2.43)	447 (254 to 955)	53.8
30%	80	1.25 (1.18 to 1.32)	12.55 (10.78 to 14.12)	10.98 (10.14 to 11.76)	0.49 (−1.52 to 2.67)	525 (322 to 1106)	56.6
30%	90	1.26 (1.20 to 1.32)	12.12 (10.50 to 13.72)	10.79 (10.01 to 11.62)	0.58 (−1.41 to 2.49)	684 (382 to 1341)	58.3
30%	100	1.25 (1.18 to 1.31)	11.98 (10.43 to 13.66)	10.56 (9.73 to 11.53)	1.00 (−1.03 to 2.97)	653 (416 to 1263)	62.0
40%	63	1.26 (1.19 to 1.32)	12.54 (10.94 to 14.33)	11.10 (10.14 to 11.92)	0.47 (−1.54 to 2.63)	494 (302 to 1012)	56.2
40%	70	1.26 (1.19 to 1.32)	12.51 (10.80 to 14.06)	10.90 (10.03 to 11.82)	0.69 (−1.44 to 2.69)	557 (339 to 1218)	58.4
40%	80	1.25 (1.19 to 1.31)	12.42 (10.75 to 13.96)	10.87 (10.03 to 11.73)	0.85 (−1.21 to 2.62)	675 (413 to 1399)	61.3
40%	90	1.25 (1.19 to 1.32)	11.92 (10.43 to 13.50)	10.70 (9.86 to 11.53)	0.69 (−1.41 to 2.89)	733 (442 to 1480)	59.5
40%	100	1.25 (1.18 to 1.32)	11.80 (10.19 to 13.40)	10.45 (9.62 to 11.44)	0.78 (−1.13 to 2.83)	930 (497 to 1934)	62.3
50%	63	1.25 (1.19 to 1.31)	12.51 (10.87 to 14.17)	10.97 (10.09 to 11.90)	0.69 (−1.54 to 2.84)	608 (347 to 1282)	58.6
50%	70	1.25 (1.19 to 1.32)	12.45 (10.86 to 14.10)	10.91 (10.04 to 11.76)	0.68 (−1.51 to 2.73)	668 (410 to 1376)	58.0
50%	80	1.25 (1.19 to 1.31)	12.00 (10.38 to 13.70)	10.61 (9.78 to 11.45)	0.81 (−1.10 to 3.03)	764 (451 to 1629)	61.4
50%	90	1.24 (1.19 to 1.31)	11.88 (10.11 to 13.65)	10.50 (9.60 to 11.52)	1.03 (−1.10 to 3.20)	768 (505 to 1695)	63.1
50%	100	1.24 (1.18 to 1.31)	11.56 (10.07 to 13.21)	10.46 (9.50 to 11.27)	1.25 (−1.00 to 3.21)	872 (566 to 1615)	64.0
60%	63	1.25 (1.19 to 1.32)	12.35 (10.69 to 13.92)	10.81 (9.96 to 11.68)	0.80 (−1.34 to 2.70)	745 (433 to 1472)	61.0
60%	70	1.26 (1.19 to 1.32)	12.27 (10.66 to 13.81)	10.78 (9.95 to 11.66)	0.68 (−1.38 to 2.50)	856 (505 to 1758)	60.4
60%	80	1.25 (1.19 to 1.31)	11.99 (10.40 to 13.60)	10.61 (9.76 to 11.47)	0.88 (−1.03 to 2.97)	859 (551 to 1776)	62.7
60%	90	1.25 (1.18 to 1.31)	11.86 (10.31 to 13.42)	10.48 (9.56 to 11.30)	1.12 (−1.07 to 3.21)	882 (577 to 1741)	62.6
60%	100	1.24 (1.17 to 1.30)	11.63 (9.97 to 13.29)	10.25 (9.30 to 11.15)	1.27 (−0.63 to 3.31)	1031 (614 to 2163)	67.6

*Calculations in this column are based only on simulations in which the number of HIV infections averted was >0.

at all NG/CT screening events, 1031 additional NG/CT tests conducted among MSM with HIV (IQR, 614 to 2163) would avert 1 new HIV infection. Across the scenarios assuming a 60% increase in NG/CT screening among MSM with HIV, between 61.0% and 67.6% of scenarios resulted in averting HIV infections compared with the base scenario depending on the proportion of screening events that included rectal STI screening.

DISCUSSION

Using a mathematical modeling framework, we sought to estimate the effect of increasing screening for NG/CT on downstream HIV incidence by HIV serostatus and anatomical site of screening. We found that the most substantial decreases in HIV incidence occurred after increases of screening for NG/CT among MSM who had 2 or more partners in a 6-month period and among sexually active MSM without HIV generally. Smaller reductions in downstream HIV incidence were observed when screening was increased among men with HIV, likely due, at least in part, to the relatively smaller population of MSM with HIV compared with MSM without HIV. At all levels of screening coverage among MSM without HIV, increased coverage of rectal screening resulted in a greater proportion of HIV infections averted; increasing rectal screening among MSM with HIV had smaller and less consistent effects. However, increased screening of MSM with HIV was more efficient at all levels we assessed, as indicated by the lower number of additional NG/CT tests per HIV infection averted for MSM with HIV compared with MSM without HIV. It is important to note that far fewer of the simulations based on scenarios of increased screening among MSM with HIV resulted in averting any HIV infections compared with scenarios of increased screening of MSM without HIV, reflecting the much smaller overall effects on HIV incidence in the former scenarios.

Because we used a network modeling approach, our results estimate the total effect of NG/CT screening on HIV incidence. The ideal outcome of a positive screening test result, treatment of NG/CT infection, has a direct effect on HIV incidence by decreasing the risk of HIV transmission or acquisition in subsequent sexual encounters. By modeling the effect of screening in a simulated network with a 10-year time horizon, we also capture reduced incidence based on the prevention of earlier HIV cases via NG/CT accelerated treatment.

Previous analyses have demonstrated the expected effects of increased NG/CT screening on NG/CT incidence[20]; our analysis expands on those results to understand the effects of NG/CT screening on HIV incidence. There is strong evidence for the synergy between the HIV and STI epidemics among MSM, including shared transmission mechanisms and risk factors.[3,4,31s] Although most community-based trials that have examined the effect of STI screening on HIV incidence have been negative,[3] they were also conducted among heterosexual populations. The effect of STI screening on HIV incidence among MSM remains an open question. We previously estimated that 10% of new HIV infections among MSM in the United States were attributable to NG/CT infection,[15] and the same proportion has been estimated to be 15% among young MSM.[16] The proportion of HIV incidence attributable to NG/CT infection provides a ceiling for the possible effect of increasing NG/CT screening and treatment on subsequent HIV infections. Thus, based on our previous estimate, one might expect that a screening program that resulted in the elimination of NG/CT among MSM would avert 10% of new HIV infections annually. In some scenarios we modeled in which screening was increased among men with 2 or more sex partners in the previous 6 months, we observed near elimination of NG and CT by the end of the 10-year follow-up period, indicating that NG/CT screening programs may achieve their maximum effect on HIV incidence within 10 years in those scenarios.

Notably, the proportion of HIV incidence attributable to NG/CT is inextricably linked to the overall prevalence of NG/CT in the population. That is, a population with a higher prevalence of NG/CT would have a larger proportion of HIV incidence attributable to NG/CT. Indeed, the initial prevalence of NG/CT in the current model is greater than in our previous work,[15] reflecting the increasing prevalence of NG/CT among MSM in recent years.[1] Thus, jurisdictions with higher prevalence of NG/CT among MSM would expect to see a greater reduction in HIV incidence after increased screening and treatment for NG/CT than our model estimates.

An important strength of our analysis is that estimates of the effect of NG/CT on HIV transmission and acquisition were anatomic site specific. That is, an increased risk of HIV acquisition or transmission only occurred in the context of a NG/CT infection at the site of sexual activity. Because NG/CT infection is anatomic site specific, the US Centers for Disease Control and Prevention recommends screening at all anatomic sites of sexual contact. Most rectal NG/CT infections are associated with a negative urogenital screen at the same clinic visit,[32s] highlighting the need for extragenital screening. Although rectal screening is an important tool for preventing onward transmission of NG/CT and reducing the risk of HIV acquisition and transmission, it is much less common than urogenital screening.[7,32s] Most rectal NG/CT infections are asymptomatic[8] and will remain undetected in the absence of a screening test. Our results demonstrate that, beyond the direct benefit of reducing NG/CT incidence, increased rectal screening, particularly among MSM without HIV, will also have downstream effects to reduce HIV incidence.

We observed much larger declines in HIV incidence after increased NG/CT screening among MSM without HIV and MSM who had at least 2 sex partners in the preceding 6 months. Of note, PrEP-eligible MSM were assumed to initiate PrEP at a rate that resulted in approximately 15% of MSM without HIV using PrEP at any given time. These men were assumed to adhere to the recommended STI screening schedule for PrEP users; thus, the observed effects of increasing NG/CT screening were a result of increasing STI screening among MSM not on PrEP. The smaller effects of increased screening among MSM with HIV are likely a reflection of the smaller population size of MSM with HIV compared with MSM without HIV and the smaller modeled effect of prevalent NG/CT on HIV transmission compared with HIV acquisition.

Our model does not estimate the effect of other STIs (e.g., syphilis) on HIV risk; thus, these results are likely an underestimate of the possible effect of STI screening in general on HIV incidence among MSM. In addition, we only estimate the effect of anal sex on HIV transmission. Infection caused by NG/CT can also occur in the pharynx, and pharyngeal NG/CT screening is recommended for MSM who engage in receptive oral sex. Oral sex is not a major risk factor for HIV; however, it does play an important role in the NG/CT epidemics.[33s] Thus, pharyngeal screening might result in the prevention of transmission of an NG/CT infection that would later be involved in an HIV transmission event. This would also indicate that our results underestimate the possible total effect of increased NG/CT screening on HIV incidence among MSM.

These data demonstrate that increasing screening for NG/CT is expected to have meaningful downstream effects on HIV incidence. The biggest impact was observed when increasing NG/CT screening among MSM without HIV and MSM who had at least 2 sexual partners in the previous 6 months; however, increasing NG/CT screening among MSM with HIV was more efficient.

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