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HIV sexual transmission risk among serodiscordant couples: assessing the effects of combining prevention strategies

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Abstract

Background: The number of strategies to prevent HIV transmission has increased following trials evaluating antiretroviral therapy (ART), preexposure prophylaxis (PrEP) and male circumcision. Serodiscordant couples need guidance on the effects of these strategies alone, and in combination with each other, on HIV transmission.

Methods: We estimated the sexual risk of HIV transmission over 1-year and 10-year periods among male–male and male–female serodiscordant couples. We assumed the following reductions in transmission: 80% from consistent condom use; 54% from circumcision in the negative male partner of a heterosexual couple; 73% from circumcision in the negative partner of a male–male couple; 71% from PrEP in heterosexual couples; 44% from PrEP in male–male couples; and 96% from ART use by the HIV-infected partner.

Findings: For couples using any single prevention strategy, a substantial cumulative risk of HIV transmission remained. For a male–female couple using only condoms, estimated risk over 10 years was 11%; for a male–male couple using only condoms, estimated risk was 76%. ART use by the HIV-infected partner was the most effective single strategy in reducing risk; among male–male couples, adding consistent condom use was necessary to keep the 10-year risk below 10%.

Conclusion: Focusing on 1-year and longer term transmission probabilities gives couples a better understanding of risk than those illustrated by data for a single sexual act. Long-term transmission probabilities to the negative partner in serodiscordant couples can be high, though these can be substantially reduced with the strategic use of preventive methods, especially those that include ART.

Keywords

acquisition; antiretroviral therapy; circumcision; condom; HIV; preexposure prophylaxis; serodiscordant couple; transmission

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Conflicts of interest

None of the authors have conflicts of interest.

Introduction

The majority of new HIV infections that occur each year are acquired through sexual contact [1]. The risk of HIV transmission in a serodiscordant couple varies widely on the basis of the type and frequency of sexual activity and viral load of the infected partner [2–4]. Condom use reduces the risk of HIV transmission during vaginal and anal intercourse and has been a key method used by serodiscordant couples to reduce their risk [5]. Recent clinical trials have expanded the options for preventing HIV infection among sexuallyactive persons. These studies show that antiretroviral drugs taken for preexposure prophylaxis (PrEP), antiretroviral therapy (ART) for treatment of HIV infection and male circumcision [6–10] significantly reduce HIV transmission risk.

It is unclear, however, how individuals in serodiscordant relationships might best use these new and existing strategies (individually or in combination) to achieve optimal levels of risk-reduction over the course of an established relationship. Currently, most behaviour change interventions evaluated in randomized trials were developed before definitive studies showed HIV acquisition reductions from PrEP of 44 and 75%, from ART of 96% and from circumcision in heterosexual men of 54% [6–12]. Understanding how these new strategies should be employed with existing strategies is needed to inform the development of new, more effective, recommendations for risk-reduction and individual decision making.

We identified no studies presenting long-term HIV transmission probabilities incorporating both updated transmission rates and risk ratios from the latest HIV clinical trials. To understand the long-term risk of HIV transmission using evidence-based strategies, we developed a model of sexual HIV transmission in serodiscordant male–male and male–female couples using transmission probabilities by type of sex act and risk ratios associated with condom use, PrEP, ART and male circumcision.

Our intent is to show how risk reduction strategies can differentially affect risk over time in a way that highlights the strengths and limitations of the various strategies. We aim to indicate the relative effects of different sexual behaviours and prevention practices on transmission risk within HIV serodiscordant partnerships. Also, given that data on intervention effects are not fully mature, we propose our model as a way to evaluate HIV risk, as additional data become available.

Materials and methods

We used a Bernoulli model to estimate HIV sexual risk. We considered four types of sexual acts, denoted i: insertive vaginal, receptive vaginal, insertive anal and receptive anal sex. Case reports suggest the possibility of HIV acquisition from receptive fellatio [13–15]; however, a systematic review was unable to provide an estimate of risk, and to the extent the risk exists, it is estimated to be low [16]; thus, oral sex was not included in this analysis. The model included four modifiers of HIV transmission risk, denoted j: condom use, PrEP, male circumcision and ART [5–10]. A risk ratio, r_j, was obtained for each of these modifiers based largely on meta-analyses and systematic reviews of transmission risk data (Table 1) [17–25]. Our primary interest was to focus on the population of the United States, and data

from the United States or high-income countries were used when available. Although sexually transmitted infections may pose an increased risk of HIV acquisition, treatment of these infections was not included as a modifier because randomized trials of acyclovir treatment for chronic HSV-2 infection showed no effect on HIV acquisition [17,26].

Table 1 presents the basic HIV transmission probabilities per act, b_i. The probabilities are described as basic because the studies referenced controlled for the potential effect of modifiers such as condom use, ART and circumcision in their analyses. A meta-analysis of HIV risk among heterosexual couples in high-income countries suggests a per-act transmission probability of 0.08% for unprotected receptive vaginal sex, 0.04% for unprotected insertive vaginal sex and a pooled estimate of 0.08% for both [17]. However, the difference in per-act transmission between receptive and insertive vaginal sex is not significant when adjusted for cofactors, suggesting that infectivity is similar for receptive and insertive vaginal sex [17]. Therefore, we used the pooled per-act transmission probability for unprotected receptive and unprotected insertive vaginal sex of 0.08% [17].

We assumed a transmission probability of 1.4% per act of unprotected receptive anal sex based on a meta-analysis [18]. We assumed a per-act HIV transmission probability for unprotected insertive anal sex among uncircumcised men of 0.62% based on a study of MSM that reported results stratified by circumcision status [19].

A systematic review suggests that consistent condom use reduces HIV transmissions by 80% when compared with nonuse, resulting in a risk ratio of 0.20 [5]. This effect was based on serodiscordant couples who self-reported using condoms for all sex acts. This study did not present a confidence interval (CI); therefore, we applied Poisson regression to the reported number of seroconversion events and person-years of observation time data and estimated a 95% CI of 0.08–0.47.

A meta-analysis combining the outcomes of three randomized controlled trials of male circumcision reported an HIV incidence risk ratio of 0.46 (95% CI 0.34–0.62) representing a 54% reduction in HIV risk from heterosexual sex among circumcised men compared with uncircumcised men [10]. From a systematic review of studies of men who practice primarily or exclusively insertive anal sex with men, we obtained a risk ratio of 0.27 (95% CI 0.17–0.44) for the effect of male circumcision on HIV acquisition [20].

For the reduction in HIV risk due to PrEP among heterosexuals, we combined the reported number of seroconversions and person-years of observation time from two trials and then used Poisson regression to estimate a risk ratio of 0.29 and a 95% CI of 0.17–0.47 [7,8]. We included these trials because adherence, measured objectively, was greater than 80%. We did not consider studies in which poor adherence may have led to failed outcomes [27,28].

A trial among MSM indicated that PrEP was associated with a risk ratio of 0.56 (95% CI 0.37–0.85) indicating a 44% reduction in HIV incidence [6]. In this study, overreporting of pill use was substantial; the rate of self-reported pill use was about 95%, although 50% of participants had detectable levels of the study drug [6]. In a subgroup analysis, those with a detectable study drug level were associated with an efficacy of 92%; we explored this in a sensitivity analysis [6].

A systematic review of ART in serodiscordant couples identified nine observational studies and one randomized controlled trial [29]. The trial demonstrated that ART reduced HIV transmission to the negative partner by a risk ratio of 0.04 (95% CI 0.01–0.27) [9]; we did not consider whether the HIV-positive patient on ART achieved viral load suppression.

Interim results of an ongoing observational study among MSM suggest that ART may eliminate the risk of HIV transmission during anal sex [30]. Until the magnitude of effect of ART among MSM is determined, we assumed that the protective effects of ARTon vaginal sex would be similar for anal sex [31–33].

Assessing risk

We focused the analyses on serodiscordant partnerships and defined three types of couples: an HIV-positive male with an HIV-negative male (M+M−), an HIV-positive female with an HIV-negative male (F+M−) and an HIV-positive male with an HIV-negative female (M+F−). We assumed six sex acts per month for each type of couple on the basis of estimates from several studies, including the National Survey of Family Growth and the National Survey of Sexual Health and Behavior [21–25].

In the base case for M+M− couples, we assumed three insertive anal sex acts and three receptive anal sex acts per month. We considered the protective effects of circumcision only for insertive sex acts. For F+M− couples, we assumed a base case of six insertive vaginal acts per month and evaluated the substitution of one vaginal act for one anal act, with and without circumcision. For M+F− couples, we assumed a base case of six receptive vaginal acts per month and evaluated the substitution of one vaginal act for one anal act.

For each couple, we varied risk modifiers, frequency and types of sex acts, and calculated the cumulative probability of HIV transmission to the negative partner over a 1-year and 10-year time horizon. The cumulative probabilities represent the risks of HIV transmission to the negative partner resulting solely from sexual exposure within the serodiscordant couple.

We assumed that risk ratios are independent and multiplicative [34]. For each type of sex act, the per-act HIV transmission probability, denoted α_i, is:

$$\alpha_i = b_i \times \prod_j r_j$$

for each modifier j present in the partnership. Risk ratios were based on risks observed over a study's entire time period and may not translate to a risk multiplier that can be used on a per-act basis; however, the potential discrepancy is reduced by presenting our results over a minimum of 72 sex acts (for the 1-year cumulative probability). The per-act HIV transmission probability is the risk from a single exposure via a sexual act within the serodiscordant couple and is treated as a Bernoulli trial [34,35]. For each type of sex act, the cumulative risk of HIV transmission to the negative partner is:

$$p_i = 1 - (1 - \alpha_i)^{n_i}$$

where n_i is the number of exposures to type of sex act i within the 1-year or 10-year time horizon. Lastly, the cumulative risk of HIV transmission to the negative partner for all types of sex acts performed within a partnership, denoted P, is estimated as:

$$P = 1 - \prod_j (1 - p_i)$$

Calculations were performed using Microsoft Excel. To assess the stability of the results, we conducted univariate sensitivity analyses on the risk ratio for each modifier and on the number of monthly sex acts over the 1-year cumulative probability of HIV transmission. We varied the parameters within the upper and lower bounds of the 95% CI of the base case input value (Table 1), with two exceptions: for PrEP, we used the greater efficacy of 92% reported for the participants with a detectable level of study medication [6] and, for the number of monthly sex acts, we assumed a low of 2 and a high of 20.

Results

For all couples, the 1-year transmission risk to the negative partner was highest (and ranged from 12 to 52%) when anal sex was practiced and lowest (and ranged from 0.05% to 0.1%) when the HIV-positive partner used ART in combination with other strategies (Tables 2–4).

In the M+M− couple, the 1-year risk of HIV acquisition was 52%, and the 10-year risk was 99.9%, when no risk-reduction strategy was employed (Table 2). The 1-year risk of HIV infection was 13%, and the 10-year risk was 76%, when consistent condom use was the only strategy employed. Only the combination of ART and condom use (together and together in combination with other strategies) lowered the 1-year risk of HIV transmission to 1% or less and the 10-year risk to 6% or less in M+M− couples. Of scenarios without ART, combining the use of PrEP, condoms and practicing insertive anal sex exclusively yielded the lowest risk of HIV with a 5% probability over one year and 39% over ten years. The use of PrEP and/or circumcision only, or practicing insertive anal sex exclusively, resulted in a 10-year cumulative probability of HIV transmission greater than 95%.

In the F+M− couple, HIV risk ranged from 0.01 to 12% over 1 year and from 0.1 to 71% over 10 years (Table 3). ART, consistent condom use and PrEP used individually, or in combination with other methods, all reduced the 1-year risk of HIV transmission to 2% or less. When consistent condom use and ART were combined, the 1-year cumulative probability of HIV transmission was below 0.05% and the 10-year probability was 0.5% or lower. Other than ART, no single strategy resulted in a 10-year cumulative probability of HIV transmission below 10%. Practicing insertive anal sex roughly doubled the risk of HIV transmission when ART, PrEP or condoms were used by themselves relative to those same scenarios wherein only vaginal sex was practiced.

In the M+F− couple, HIV risk ranged from 0.05 to 20% over 1 year and from 0.5 to 89% over 10 years and, the 1-year risk of HIV transmission to the female partner more than tripled when receptive anal sex was practiced with and without condoms (Table 4). PrEP or consistent condom use without receptive anal sex, and ART (alone or in combination)

reduced the 1-year risk of HIV transmission to 2% or less. PrEP and condom use (without receptive anal sex) was the only dual strategy that did not include ART to reduce the 10-year risk below 10% (Table 4).

Validation

To validate the model and inputs, we compared the HIV transmission probabilities projected by the model against observed data from longitudinal studies. We identified two studies of heterosexual serodiscordant couples with sufficient data and follow-up times to establish an annual HIV incidence rate. We identified no studies of MSM serodiscordant couples that could provide an incidence rate for comparison against the HIV transmission probabilities of M+M− couples suggested by the model.

The control arm of the HPTN052 trial followed 877 serodiscordant couples over a median of 1.7 years and observed 27 partner-linked HIV transmissions, representing an incidence of 0.017 per person-year (95% CI 0.011–0.025) [9]; 95% of trial participants reported 100% condom use, weekly coital frequency averaged 1.6 and circumcision rates among negative men was 14%. We replicated these input conditions and the model results projected a 1-year HIV transmission probability of 0.016 and 0.015 per year for M+F− and F+M− couples, respectively.

Similarly, in a trial evaluating the effect of treating herpes on HIV transmission, the placebo group included 1677 serodiscordant couples not taking ART [26]. A total of 43 partner-linked seroconversions were observed over 2290 person years of follow-up with a male-to-female incidence rate of 0.025 cases per person year (95% CI 0.14–0.037) and a female-to-male incidence rate of 0.15 cases per person year (95% CI 0.009–0.022). At baseline, 93% of trial participants reported 100% condom use, the mean number of sex acts in the previous month was 6 and circumcision rates among negative men was 55%. We replicated these input conditions and model results projected a 1-year HIV transmission probability of 0.015 and 0.011 per year for M+F− and F+M− couples, respectively. Concordance between our model results and the CIs for HIV incidence rates suggested in these two trials demonstrates the robustness of the model structure and its inputs and findings for heterosexual couples.

Sensitivity analysis

Varying the frequency of sex and the efficacy of PrEP had the largest effect on the 1-year probability of HIV transmission among M+M− couples (Fig. 1).

Assuming that no protective strategies were used, when the number of monthly sex acts was increased from a base case of six to 20, the 1-year probability of HIV transmission increased from 52 to 91%. When the monthly acts of anal sex was decreased from six to two, the 1-year probability of HIV transmission decreased from 52 to 22%. Varying sex frequency in scenarios with ART was associated with variations in the 1-year transmission probability of at most 5 percentage points.

Among M+M− couples, improving the effect of PrEP from 44 to 92%, to reflect the efficacy among those who had a detectable level of study medication, the 1-year probability of HIV transmission, when PrEP was used alone, decreased to 6% (from 34%).

We performed sensitivity analyses on the 1-year probability of HIV transmission for M+F− and F+M− couples that resulted in similar patterns than that observed by the sensitivity analyses for M+M− couples, though with a less effect on the results (see Figure A.1, http://links.lww.com/QAD/A522 and A.2 in appendix, http://links.lww.com/QAD/A522).

Discussion

This analysis is the first to use current HIV transmission rates and risk ratios in a comprehensive way to present long and short-term HIV risk estimates. The analysis highlights three main points. First, modest HIV transmission probabilities per sex act translate into substantial cumulative risks over time. In serodiscordant couples, particularly those practicing anal sex, some strategies (including consistent condom use) may not provide sufficient levels of protection over an extended time when used alone. Second, ART had the most substantial protective effect of any strategy. However, even with ART use, HIV risk may be unacceptably high among M+M− couples. Lastly, anal sex substantially increases the risk of HIV transmission. The risk of transmission over time for M+M− couples practicing anal sex is dramatically higher than that of M+F− and F+M− couples practicing the same number of vaginal sex acts because, relative to vaginal sex, anal sex is associated with an eight-fold increase in risk of transmission per insertive act and an 18-fold increase per receptive act. Among M+F− and F+M− couples, having one act of anal sex each month substantially increased the risk of HIV transmission over time.

Results suggest that HIV transmission probabilities to the negative partner in M+M− couples who have anal sex may be kept at 10% or lower, over a 10-year horizon, only when ART and condoms are used together or in combination with other strategies. HIV transmission probabilities among F+M− couples were 10% or lower over a 10-year horizon with no condom use if the positive partner was taking ART or the negative partner was circumcised and taking PrEP. HIV transmission probabilities among M+F− couples were 10% or lower over a 10-year horizon with no condom use only if the positive partner was taking ART.

The sensitivity analyses suggests that when ART is used, HIV risk is less sensitive to the effect of variations in the input parameters presumably because the risk of HIV transmission is lowest in the presence of ART. Also, the cumulative probability of HIV transmission changes most when the frequency of sex acts is varied. Lastly, increasing PrEP efficacy among male-male couples to account only for those with detectable drug levels reduces the 1-year probability of transmission from 34 to 6%. Therefore, high adherence to the ART regimen for PrEP is essential and strategies to promote high adherence are necessary to achieve the maximum benefits of PrEP.

The effectiveness of condoms is based on self-reported consistent condom use. Social desirability biased responses, for example those over-reporting condom use, would underestimate condom efficacy, causing our risk estimates to be too high. Conversely, assuming consistent condom use for all sex acts over a 1-year or 10-year timeframe may be optimistic, resulting in risk estimates that are too low. In a study of HIV-negative MSM, 42% reported unprotected insertive anal sex with a positive main partner, and 20% reported unprotected receptive anal sex with a positive main partner [36]. Studies of condom use

suggest little or no effectiveness when use is not consistent [37–40]. Albeit difficult, consistent use is essential to achieve the protective effects of condoms over time.

Studies have shown a two-fold to three-fold increase in HIV infectivity per $\log_{10}$ increase in plasma viral load [9,41,42], although the relationship is not linear [43]. About 80% of people on ART have undetectable viral loads (less than 200 copies/ml) [44,45]; among those with detectable viral loads, some have lower levels than without any ART. Our model establishes a dichotomous relationship between infectivity and ART status in the positive partner and does not account for fluctuations in viral load. Therefore, in partnerships wherein the positive partner has an inherently low viral load set-point and is not on ART, or wherein the positive partner adheres poorly to ART, the model's projected HIV transmission probabilities may be overestimated or underestimated, respectively.

Data from couples suggest that HIV transmission risk from sex in serodiscordant couples may level off over time, regardless of ongoing exposures [18]. To the extent that this occurs, our cumulative transmission risks may be overestimated. Lack of data on the effects of length of partnership, outside exposures, condom use and frequency and type of sex acts, on transmission risk among serodiscordant couples makes exploration of this issue difficult, although it may relate to variability in susceptibility and infectiousness [18,46]. More research would be useful on why the risk of HIV acquisition appears to wane following repeated exposures from a partner.

Interim data on the magnitude of effect support our assumption that the protective effects of ART for anal sex are similar to the effects for vaginal sex [30]. Should studies demonstrate that ART is less effective at reducing HIV transmission during anal sex than during vaginal sex, then HIV transmission over time for serodiscordant male couples on ART would be even greater than our results suggest.

Lastly, empirical data on the efficacy of intervention combinations are lacking, difficult to measure and were not considered in the model. As with other HIV epidemic models, uncertainty surrounds the assumptions and parameter values used; data on efficacy of intervention bundles, risk behaviours, adherence and effect of ARTon MSM would enable more reliable projections. We expect that this analysis will be updated as new data become available.

The strength of our study is twofold: first, presenting long-term HIV risks may substantially improve risk prevention messaging; and second, showing the relative contribution of sexual behaviours and HIV prevention strategies to the risk of HIV transmission improves couples' understanding of HIV risk, and hence, their decisions. This model was not designed to predict actual transmission risk for real-world serodiscordant couples over the course of a multiyear relationship. Rather, our intent is to emphasize how risk accumulates over time under various strategies and show the relative differences between strategies.

Our findings address important issues for the 34 million people living with HIV worldwide and their noninfected partners. As options for reducing HIV acquisition risk expand and people with HIV live longer, healthier lives, information regarding HIV transmission become increasingly important. Individuals in serodiscordant relationships need to

understand how best to minimize the risk of HIV transmission using effective strategies that are affordable and can be maintained over time. Focusing on 1-year and 10-year transmission probabilities gives couples a better understanding of HIV risk than those illustrated through single sexual acts. Research on sexual decision-making and ways to increase the adoption of effective HIV prevention strategies are urgently needed.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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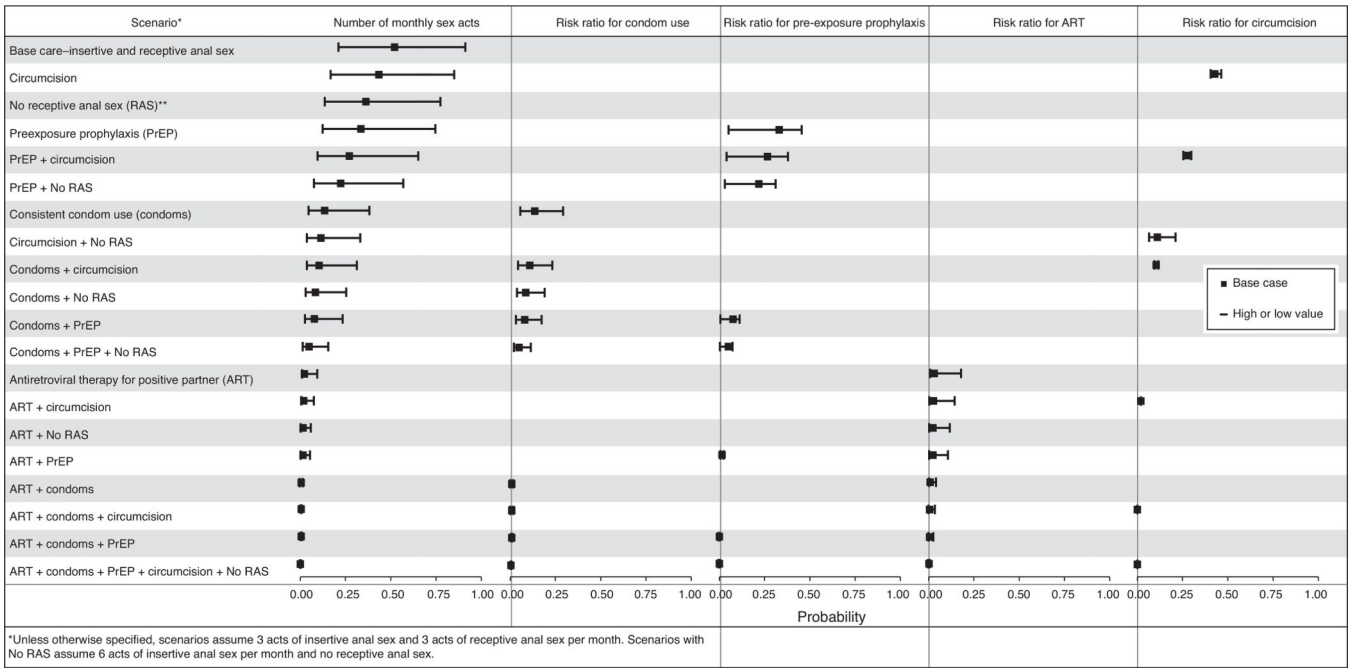

Fig. 1.

Impact of sensitivity analysis on 1-year cumulative probability of HIV transmission in serodiscordant male couples.

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Table 1.

Input data.

Variable	Value[a]	Source
Probability of HIV transmission per unprotected sex act with an infected partner (b_i) [95% CI]		
Insertive vaginal sex	0.0008 [0.0006–0.0011]	[17]
Receptive vaginal sex	0.0008 [0.0006–0.0011]	[17]
Insertive anal sex	0.0062 [0.0007–0.0168]	[19]
Receptive anal sex	0.014 [0.002–0.025]	[18]
Risk ratio associated with HIV transmission risk modifiers (r_j) [95% CI]		
Positive partner taking ART	0.04 [0.01–0.27]	[9]
Condom use[b]	0.20 [0.08–0.47]	[5]
Male circumcision in negative partner of MSM couple	0.27 [0.17–0.44]	[20]
PrEP in heterosexual couple[b]	0.29 [0.17–0.47]	[7,8]
Male circumcision in negative partner of heterosexual couple	0.46 [0.34–0.62]	[10]
PrEP in MSM couple	0.56 [0.37–0.85]	[6]
Number of monthly sex acts	6	[21–25]

ART, antiretroviral therapy; CI, confidence interval.

[a]Unless otherwise specified, probabilities, risks and confidence intervals reported are from the referenced studies.

[b]Relative risk and 95% confidence interval are calculated by applying Poisson regression to the reported number of seroconversions and person-years of observation time.

Table 2.

Annual and 10-year probability of HIV transmission in serodiscordant male couples with varying combinations of risk modifiers.

Scenario[a]	Cumulative probability of HIV transmission	
	1 year	10 years
Base case – insertive and receptive anal sex	52%	99.9%
Circumcision	43%	99.7%
No receptive anal sex (RAS)	36%	99%
Preexposure prophylaxis (PrEP)	34%	98%
PrEP and circumcision	27%	96%
PrEP and no RAS	22%	92%
Consistent condom use (condoms)	13%	76%
Condoms and circumcision	11%	70%
Circumcision and no RAS	11%	67%
Condoms and PrEP	8%	59%
Condoms and no RAS	8%	55%
Condoms and PrEP and No RAS	5%	39%
Antiretroviral therapy for positive partner (ART)	3%	25%
ART and PrEP	2%	20%
ART and circumcision	2%	16%
ART and no RAS	2%	15%
ART and condoms	1%	6%
ART and condoms and circumcision	0.4%	4%
ART and condoms and PrEP	0.3%	3%
ART and condoms and PrEP and circumcision and no RAS	0.1%	1%

[a]Unless otherwise specified, scenarios assume that the negative partner engages in three acts of insertive anal sex and three acts of receptive anal sex per month with the infected partner. Scenarios with no RAS assume six acts of insertive anal sex per month and no receptive anal sex.

Table 3.

Annual and 10-year probability of HIV transmission in couple with an HIV-positive female and an HIV-negative male partner with varying combinations of risk modifiers.

Scenario[a]	Cumulative probability of HIV transmission	
	1 year	10 years
Insertive anal sex (IAS)	12%	71%
Base case – vaginal sex only, no anal sex	6%	44%
PrEP and IAS	5%	43%
Circumcision and IAS	4%	34%
Circumcision	3%	23%
Condoms and IAS	2%	22%
Preexposure prophylaxis (PrEP)	2%	15%
Consistent condom use (condoms)	1%	11%
Condoms and PrEP and IAS	1%	10%
PrEP and circumcision	0.8%	7%
Condoms and circumcision	0.5%	5%
ART and IAS	0.5%	5%
Condoms and PrEP	0.3%	3%
Antiretroviral therapy for positive partner (ART)	0.2%	2%
ART and circumcision	0.1%	1%
ART and PrEP	0.1%	1%
ART and condoms	0.05%	0.5%
ART and condoms and circumcision	0.02%	0.2%
ART and condoms and PrEP	0.01%	0.1%
ART and condoms and PrEP and circumcision	0.01%	0.1%

[a]Unless otherwise specified, scenarios assume six acts of insertive vaginal sex per month. Scenarios with IAS assume one act of insertive anal sex and five acts of insertive vaginal sex per month.

Table 4.

Annual and 10-year probability of HIV transmission in couple with an HIV-positive male and an HIV-negative female partner with varying combinations of risk modifiers.

	Cumulative probability of HIV transmission	
Scenario[a]	**1 year**	**10 years**
Receptive anal sex (RAS)	20%	89%
PrEP and RAS	10%	66%
Base case – vaginal sex only, no anal sex	6%	44%
Condoms and RAS	4%	35%
Condoms and PrEP and RAS	4%	35%
Preexposure prophylaxis (PrEP)	2%	15%
Consistent condom use (condoms)	1%	11%
ART and RAS	0.9%	8%
Condoms and PrEP	0.3%	3%
Antiretroviral therapy for positive partner (ART)	0.2%	2%
ART and PrEP	0.1%	1%
ART and condoms	0.05%	0.5%
ART and condoms and PrEP	0.05%	0.5%

[a]Unless otherwise specified, scenarios assume six acts of receptive vaginal sex per month. Scenarios with RAS assume one act of receptive anal sex and five acts of receptive vaginal sex per month.