Reducing the Risk of Sexual HIV Transmission

Quantifying the Per-Act Risk for HIV on the Basis of Choice of Partner, Sex Act, and Condom Use

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Background: **Sexual acquisition of HIV is influenced by choice of partner, sex act, and condom use. However, current risk-reduction strategies focus mainly on condom use.**

Goal: **To estimate the contribution of choice of partner, sex act, and condom use on the per-act relative and absolute risks for HIV infection.**

Study Design: **Per-act relative risk for HIV infection was calculated with use of estimates of HIV prevalence, risk of condom failure, HIV test accuracy, and per-act risk of HIV transmission for different sex acts. Absolute risks were calculated on the basis of these relative risk estimates.**

Results: **Choosing a partner who tested negative instead of an untested partner reduced the relative risk of HIV infection 47-fold; using condoms, 20-fold; and choosing insertive fellatio rather than insertive anal sex, 13-fold. Choosing one risk-reduction behavior substantially reduces absolute risk of HIV infection for heterosexuals but not for men who have sex with men.**

Conclusion: **Clarifying the magnitude of risk associated with different choices may help people make effective and sustainable changes in behavior.**

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FOR AN UNINFECTED PERSON, every sexual encounter presents a risk of acquiring HIV. In the United States each year, about 20,000 persons acquire HIV infection through sexual contact.[1,2] The magnitude of the risk for an individual depends on various factors, including choice of partner, sex act, and condom use. Investigators have recommended different strategies for addressing these factors. Some have recommended reducing the number of sexual partners, avoiding high-risk sexual acts such as anal sex, and educating the public on the advantages of the use of condoms and voluntary HIV testing and counseling.[3–6] Others have advised uninfected persons to have sex with only low-risk or uninfected partners.[7,8] Most of these investigators did not quantify risks in a way that would help compare the effects of their choices.

Individuals develop a personal HIV-infection prevention strategy by making choices that are associated with different risks and benefits. Ideally, effective choices are based on an accurate perception of the risks from different combinations of behaviors. Often, however, the perceived hierarchy of risks from different activities may not match the data from epidemiologic studies.[9] The risk of acquiring HIV sexually depends on choice of partner, choice of sex act, and condom use. Accurate information on the magnitude of risks and benefits of each of these choices could substantially improve efforts to prevent HIV infection.

Recent studies have provided valuable information on the sensitivity of newer tests for HIV,[10,11] effectiveness of condom use,[12–14] and risk for HIV infection associated with different sex acts.[15–29] Our objective was to estimate the per-act relative and absolute risks of acquiring HIV infection during sexual contact on the basis of the choices of partner, sex act, and condom use.

Methods

We calculated the overall relative risk for HIV acquisition on the basis of estimates of HIV prevalence, sensitivity of enzyme immunoassay, per-act relative risk of HIV transmission, and per-act probability of condom failure. We assumed these relative risks were independent and multiplicative (in the arithmetic scale), allowing the estimation of the overall relative risk. Parameter estimates were identified

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Received for publication February 27, 2001, revised May 16, 2001, and accepted May 18, 2001.

TABLE 1. Per-Act Relative Risk (RR) for Acquisition of HIV Based on Choice of Partner, Sex Act, and Condom Use

Partner Status*	RR	Sex Act	RR	Condom Use	RR
Heterosexual					
Negative HIV test	1	Insertive fellatio†	1	Yes[14]	1
Unknown serostatus	47	Receptive fellatio†	2	No[14]	20
HIV$^+$	4706	Insertive vaginal[21]	10		
Men who have sex with men		Insertive anal[21]	13		
Negative HIV test	1	Receptive vaginal[21]	20		
Unknown serostatus	43	Receptive anal	100		
HIV$^+$	430				

*Calculated by the authors on the basis of literature estimates, as outlined in Methods.
†Best-guess estimate.

through an extensive literature review. When published estimates were not available, we used best-guess estimates. We performed sensitivity and threshold analyses to determine the robustness of these estimates.

Choice of Partner

The value associated with the choice of partner is the probability that the partner is HIV-infected. This value depends on the assessment of the partner's risk, the partner's HIV test history, and the prevalence of HIV in the community. Assessing partner's risk is probably influenced by demographic factors such as age, residence, and medical factors (e.g., history of sexually transmitted disease [STD] and current ulcers). However, for our analysis, if the serostatus of a partner was unknown, we assumed the probability this partner was infected would be equal to the HIV prevalence in the community. We further assumed this prevalence would be 10% for men who have sex with men and 1% for heterosexuals attending HIV/STD clinics.[30,31] If a partner had tested positive for HIV, we assumed the test algorithm had no false-positives and that the partner was HIV-infected. If a partner had tested negative since the most recent sexual contact, the probability that this partner was HIV-infected was 1 minus the negative predictive value of the test, which equals [(1 − sensitivity of test) × (prevalence)]/[(1 − sensitivity of test) × (prevalence) + (1 − prevalence) × (specificity of test)].[32] The specificity of the current test for HIV antibodies is 99.8%, and the sensitivity is 99.9%.[10,11] However, in this study the sensitivity of the test for infection is lower than the sensitivity for detecting antibodies because some persons had been infected recently and antibodies had not yet developed.

To estimate the proportion of infected persons who had acquired the infection recently, we estimated that there are a total of 750,000 infected persons,[1,33] 67% of whom already know about their infection and thus would not be taking a test.[34] If 40,000 new infections occur each year[1,33] and it takes 1.5 months on average for antibodies to develop after infection is acquired,[35] on any given day there would be 40,000 × (1.5/12) = 5,000 persons with infections too recent for antibodies to have developed. These 5,000 infected persons who would test negative represent 2% of the 250,000 infected persons who do not know their serostatus. Therefore, we reduced the published sensitivity of the test for antibodies by this 2% and estimated the sensitivity for detecting infection as 97.9% (99.9% − 2%). Thus, the probability of being infected despite a negative test is 0.000213 for heterosexuals when prevalence is 1% and 0.00233 for men who have sex with men when prevalence is 10%. Thus, compared with choosing a partner who tested negative, choosing a partner with unknown serostatus among heterosexuals would increase the relative risk of HIV acquisition by 47-fold (0.01/0.000213), and choosing an HIV-positive partner would increase risk by 4706-fold (1/0.000213) (Table 1).

Choice of Sex Act

The per-act risk of HIV transmission for a given sex act is very difficult to estimate. We reviewed cross-sectional studies, cohort studies, and models that estimated per-contact risk for HIV infection.[15–29] We used the odds ratios from a large study of heterosexual couples by the European Study Group[21] to estimate the per-act relative risk associated with various sex acts (e.g., for anal sex versus vaginal sex). The report of that study included cross-sectional data on HIV-positive and HIV-negative partners of infected persons, as well as follow-up data on discordant couples. It provided the data necessary to estimate odds ratios for various sex acts. In that study, the odds ratio for male-to-female transmission versus female-to-male transmission was approximately 2, so we assumed receptive vaginal sex was twice as risky as insertive vaginal sex, per act. The odds ratio for receptive anal sex was approximately 5, so we assumed receptive anal sex was five times riskier than receptive vaginal sex, per act. Similarly, the odds ratio for insertive anal sex was 1.3, so we assumed insertive anal sex was 1.3 times riskier than insertive vaginal sex, per act. Although there are few data on the relative risks associated with fellatio (oral-penile contact), most investigators suggest that it is safer than vaginal sex. We assumed that insertive fellatio was 10 times less risky than insertive

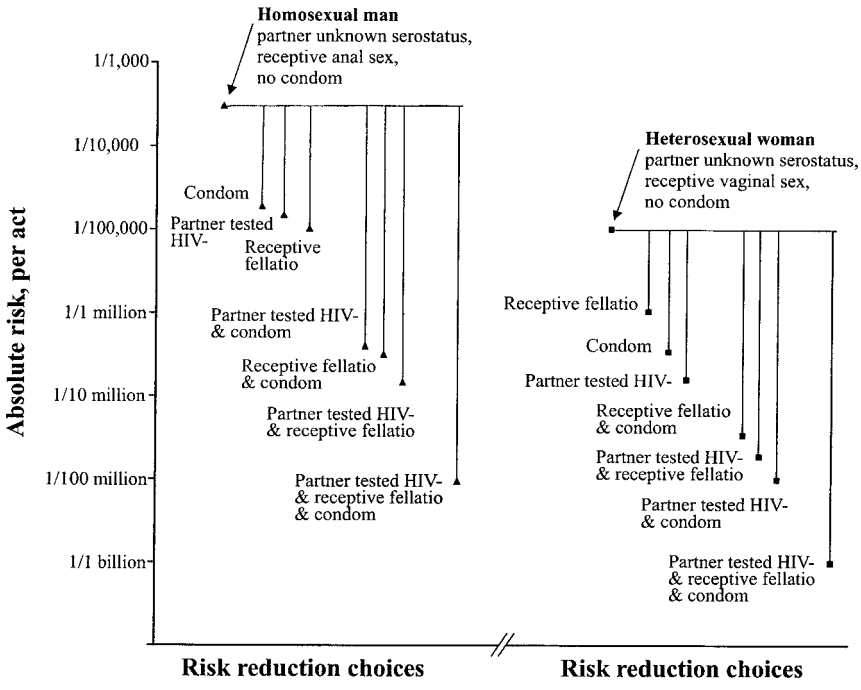

Fig. 1. Changes in risk for HIV infection based on choices of partner, sex act, and condom use. Two examples were used as referent to depict ways of reducing per-act absolute risk for HIV infection. Individuals can reduce their risk by choosing a partner who has tested HIV-negative, a safer sex act, condom use, or a combination of these.

vaginal sex and that receptive fellatio was 10 times less risky than receptive vaginal sex, per act (Table 1).

To convert from relative risks to absolute risks, we estimated that the per-act risk of HIV transmission from an infected male to an uninfected female during receptive vaginal sex without the use of condoms was 0.1%.[28] All other per-act risk estimates were calculated by either multiplying or dividing this estimate by the corresponding relative-risk estimates.

Use of Condoms

A pooled analysis of studies suggested that condoms are 90–95% effective in preventing HIV transmission, if used consistently.[12] Model-based estimation also indicated that condoms decrease the per-act probability of male-to-female transmission by about 85–95%.[13] Another study reported that condoms broke or slipped off in approximately 4% of coital acts.[14] For our model we assumed the per-act probability of condom failure due to incorrect use, slippage, and breakage to be 5%. Hence, using a condom provides a 20-fold decrease in risk of acquiring HIV infection, per act.

Results

The choice of partner and knowledge of the partner's HIV infection status had the greatest influence on the risk of HIV acquisition. For heterosexual men and women, having sex with a partner who tested negative for HIV reduced risk 47-fold in comparison with the risk of having sex with a partner of unknown serostatus (Table 1). The relative risks for choice of partner were different for men who have sex with men than for heterosexual men and women, because of the higher HIV prevalence among men who have sex with men. The reduction in relative risk of HIV infection differed widely for different sex acts. Choosing receptive fellatio instead of receptive anal sex reduced risk 50-fold, compared with a 13-fold reduction for choosing insertive fellatio instead of insertive anal sex. Condom use provided a 20-fold reduction in risk (Table 1).

There were many combinations of these choices for men who have sex with men and for heterosexual men and women. The overall relative risk was lowest when a person chose a partner who had tested negative (1), had insertive fellatio (1), and used a condom (1): the overall relative risk was 1 (referent group) (Table 1). With the same partner, insertive vaginal sex (10) while still using a condom increased the relative risk to 10. Insertive vaginal sex (10) without a condom (20) with this partner increased the relative risk to 200. The overall relative risk was highest when a person had receptive anal sex (100) with a partner who was HIV-positive (4700); without a condom (20), the overall relative risk was 9,400,000.

The absolute per-act risk of acquiring HIV was highest (5 per 1,000) when a person had receptive anal sex without a condom with an HIV-positive partner. For a man who had receptive anal sex without a condom with a male partner of unknown serostatus (HIV prevalence, 10%), the per-act risk for HIV infection was 5 per 10,000 (Figure 1). For this individual, the absolute per-act risk still remained considerable (between 1 and 2.5 per 100,000) if only one risk-

reduction behavior was adopted. Although this per-act risk seems low, the cumulative risk is high if the behavior continues for several years. For example, at a per-act risk of 2 per 100,000, a rate of engagement in sex of once a day (assuming constant risk) would result in infection of more than 7% of people within 10 years $[1 - (0.999980)^{3650}]$. Adopting two risk-reduction behaviors reduces risk substantially (to between 2 and 6 per 10 million). For example, receptive fellatio without a condom with a partner who tested negative reduces per-act absolute risk to 2 per 10 million (Figure 1). For a heterosexual woman who has receptive vaginal sex without a condom with a partner of unknown serostatus (HIV prevalence, 1%), the risk of acquiring HIV infection in a single sex act would be 2 per 100,000 (Figure 1). Choosing one risk-reduction behavior reduces this per-act risk substantially (to between 2 and 10 per 10 million).

The differences in absolute risk associated with various choices between these two examples of a man who has sex with a man and a woman who has sex with a man are mainly due to the difference in HIV prevalence among their partners. Many heterosexuals and persons in areas of low prevalence could reduce risk with a single risk-reduction step. However, because of high HIV prevalence among potential partners, men who have sex with men and many injection drug users would need to adopt at least two safer sexual behaviors to achieve a comparable reduction in absolute risk. For them, changing one behavior may not be enough to prevent acquisition of HIV during a lifetime of sexual activity.

Threshold and Sensitivity Analysis

We evaluated the robustness of our overall relative risk estimates by conducting threshold and sensitivity analyses on results that were dependent on either our calculations or our best guess. We performed threshold analysis to determine the extent to which parameters must change before overall relative risk becomes the same for different choices. For example, unprotected fellatio was found to be safer than protected receptive anal sex with the same partner. Receptive fellatio (2) without a condom (20) with a partner who tested negative (1) had an overall relative risk of 40. Receptive anal sex (100) with a condom (1) with this same partner had an overall relative risk of 100. The overall relative risks associated with these choices would be equal if the difference in relative risk of the sex acts decreased from 50 to 20 or if condom effectiveness increased from 95% to 99%.

For a given sex act, unprotected sex with a partner who tested negative would be safer than protected sex with a partner of unknown serostatus. For example, for insertive anal sex (13) without a condom (20) with a partner who tested negative (1), the overall relative risk was 260. For this same sex act (13) with a condom (1) with a partner of unknown serostatus (47), the overall relative risk was 611. The overall relative risk associated with these choices would be equal when the sensitivity of the test for infection (97.9%) equals condom effectiveness (95%).

We conducted sensitivity analysis of estimates of HIV prevalence and per-act relative risk for insertive and receptive fellatio to examine the effect of change in these on the overall relative-risk combinations. HIV prevalence influences the predictive value of the HIV tests and therefore affects the *absolute* value of the probability that a partner is HIV-infected. However, prevalence does not influence the *relative* differences in these estimates until HIV prevalence increases to more than 30%. For example, when HIV prevalence was 1% among partners, choosing a partner with a negative test reduced relative risk 47-fold, and if prevalence among partners increased to 40%, choosing a partner with a negative test reduced risk 30-fold.

The order of relative risks for all choices remained quite robust for different estimates, with one exception: fellatio. Attempts to measure the risk of transmission by fellatio are difficult because few people know the infection status of all their partners, and many who perform fellatio also have other types of sexual contact.[26] We estimated that receptive fellatio was 10 times less risky than receptive vaginal sex. Nevertheless, it is possible that receptive fellatio is only 5 times less risky, which would change the values of the overall relative-risk combinations, and the relative risk of transmission of HIV by fellatio would be closer to that for insertive vaginal or anal sex. However, it would remain substantially less risky than receptive anal sex.

Discussion

Our model confirms what seems to be intuitively obvious: sexually active persons can reduce their risk of acquiring HIV by choosing a partner who has tested negative for HIV, by choosing sex acts that are less likely to transmit HIV infection, or by choosing to use condoms. However, many persons engaging in risk-related behavior have misconceptions about the risks of different behaviors.[36] Estimates of the magnitude by which different choices might reduce the risk of HIV acquisition could help individuals make more effective choices about behaviors that reduce their risk.

An individual's choices of partner and sexual behavior are based on both the risk of acquiring an infection and the benefits derived from the sexual relationship. Our model indicates that the choice of partner is the most important factor determining the risk for HIV infection. However, individuals often rely on implicit theories about their partners' personal characteristics or social networks to determine their level of HIV risk, and they do not ask about their partners' HIV status.[37] This self-assessment of risk might be of value, because choosing a "safe" partner over a "risky" partner can reduce risk of HIV acquisition. For example, for

a heterosexual man, having sex with his wife is a lower-risk activity than having sex with a commercial sex worker. However, it is often difficult to assess a potential partner's risk.[38]

Our model illustrates that choosing a partner who has tested negative for HIV reduces risk 47-fold, compared with the risk associated with choosing a similar partner of unknown serostatus. Ensuring that a partner is HIV-negative can be one of the most effective strategies for prevention of HIV infection. Many couples have recognized the value of this approach and seek HIV testing together. In addition, having a partner in a mutually monogamous relationship undergo retesting is another effective risk-reduction strategy, because a repeatedly negative test nearly eliminates any chance that the partner is infected. Promoting discussion of HIV status with prospective sex partners should be an important component of HIV-infection prevention efforts. New HIV testing technologies could further facilitate the acceptance of this approach by allowing persons to receive test results more quickly or even test themselves at home.

Choosing a safer sex act is another way to reduce risk. This approach seems to have been adopted by many homosexual men who have more oral sex and less anal sex than in the past.[39] We believe our risk hierarchy for sex acts is in the correct order, although the magnitude of the differences in their risk is uncertain. Our estimates of the relative risk were based on odds ratios that were calculated primarily from cross-sectional data.[21] Accurate estimates of per-act relative risk are difficult to determine because investigators cannot recruit sufficient numbers of people who practice only certain sex acts and cannot ensure the absence of other infected partners. Furthermore, studies that follow discordant couples are associated with biases because investigators start with couples who have been sexually active without transmitting infection and exclude contacts during primary HIV infection.[40] Thus, it seems unlikely that the estimates of risk of HIV infection associated with specific sex acts will be much more accurate in the near future.

It is important to note that we estimated the risk for HIV infection during a single act. When multiple acts over a period of time are considered, frequency of sex and number of partners are important contributors to cumulative risk. In this context, choosing safer sex acts could lead to other behavior changes that increase risk. For example, oral-genital contact may be less efficient at HIV transmission than other sex acts, but if oral sex is practiced more frequently or with risky partners (because it is perceived to be safe), it could increase the risk for HIV infection.[39] Similarly, having a larger number of partners increases the likelihood of exposure to an infected or highly infectious partner.[41]

Promoting condom use has been the mainstay of HIV prevention strategies. The literature suggests that consistent use of condoms can reduce HIV transmission by 85% to 95%, but most study findings suggest that increasing the effectiveness beyond 95% will be difficult because of slippage, breakage, and incorrect use.[12,13] In practice, inconsistent use may reduce the overall effectiveness of condoms to as low as 60–70%.[42,43] Data from a cross-sectional study suggested that condoms failed 13% of the time, resulting in potential exposure to STDs, including HIV.[44]

This study has some limitations. First, we did not consider parenteral exposures, such as those for injection drug users or health care workers. Even for the sexual transmission group, we did not include risk estimates for cunnilingus because almost no information is available on the risk of this sex act versus that for other sex acts. Second, we did not consider other factors that might influence risk of HIV transmission, such as varying infectivity in stages of HIV infection, viral load, circumcision status, and concurrent STD.[45] We also did not consider the influence of drugs and alcohol on individuals' ability to make choices. Third, choosing a partner who has tested negative for HIV or choosing a safer sex act does not necessarily protect against STD or unwanted pregnancy. Fourth, our estimates of the prevalence of HIV among potential partners (1–10%) would vary greatly for different individuals. While this would have little effect on the relative risk reduction associated with different choices, it would change the absolute risk for HIV infection. Finally, our per-act absolute risk estimate for receptive vaginal sex was based on a model that assumed constant infectivity and the same risk over all sex acts.[24] Other studies have provided a wide range of estimates (0.05–13%) based on different populations and different models,[40] which would change the absolute risk but not the relative risk estimates.

We believe these estimates will help people better understand the risks for HIV infection that are associated with different choices. Individuals could eliminate all risk of sexual acquisition of HIV by eliminating all sexual contact. Short of that, any sexual contact brings some risk of infection (which we have estimated) and some pleasure (which individuals can determine). We hope that people use this information to choose a combination of risk-reduction behaviors they will be able to sustain.

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