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The Efficacy of Serostatus Disclosure for HIV Transmission Risk Reduction

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Abstract

Interventions to assist HIV+ persons in disclosing their serostatus to sexual partners can play an important role in curbing rates of HIV transmission among men who have sex with men (MSM). Based on the methods of Pinkerton and Galletly (*AIDS Behav* 11:698–705, 2007), we develop a mathematical probability model for evaluating effectiveness of serostatus disclosure in reducing the risk of HIV transmission and extend the model to examine the impact of serosorting. In baseline data from 164 HIV+ MSM participating in a randomized controlled trial of a disclosure intervention, disclosure is associated with a 45.0 % reduction in the risk of HIV transmission. Accounting for serosorting, a 61.2 % reduction in risk due to disclosure was observed in serodiscordant couples. The reduction in risk for seroconcordant couples was 38.4 %. Evidence provided supports the value of serostatus disclosure as a risk reduction strategy in HIV+ MSM. Interventions to increase serostatus disclosure and that address serosorting behaviors are needed.

Keywords

HIV serostatus disclosure; Prevention of sexual transmission; Mathematical models; Men who have sex with men

Introduction

Based on information published by the Centers for Disease Control and Prevention (CDC), men who have sex with men (MSM) remain disproportionately represented in national HIV/AIDS statistics. In 2009, MSM accounted for approximately 2 % of the US population but

more than 60 % of all adolescent/adult HIV diagnoses. At the end of 2009, MSM accounted for more than 50 % of all persons living with HIV (PLWH) [1]. Among MSM, the greatest risk of infection is through sexual risk behavior, and unprotected anal intercourse is the activity associated with the highest risk of transmission [1].

In 2003, the CDC announced its *Advancing HIV Prevention* program which focused prevention efforts on testing, medical care, and risk reduction in PLWH [2]. In their recommendations for HIV prevention among PLWH the CDC acknowledged the importance of serostatus awareness through testing and serostatus disclosure to the reduction of transmission risk in serodiscordant couples [3]. Disclosure, defined as the act of informing a sexual partner of one's own positive serostatus, can lead to reduced risk of transmission through seroadaptation. Seroadaptive strategies which might limit the risk of transmission include abstinence, avoiding intercourse, avoiding anal intercourse, condom use, serosorting, withdrawal, or seropositioning [4–6]. Recent research has also underscored the importance of viral load suppression to the reduction in transmission of HIV [7].

To date, extant research regarding the relationships between HIV disclosure, seroadaptation, and risky sexual behavior in HIV positive MSM has generally shown a protective effect of disclosure on the risk of transmission [8–15]. In a 1998 study, De Rosa and Marks [10] found that condom use was significantly greater when partners were informed of a positive serostatus. Similarly, Kalichman and Nachimson [11] found that condom use was significantly lower among MSM who had not disclosed. In a more recent study, Bird and colleagues found that disclosure to HIV-negative partners resulted in lower risks of HIV transmission, regardless of the race of the individual disclosing [9].

The criminalization of HIV transmission has also served to underscore the importance of disclosure for HIV positive MSM. As of 2013, 33 states have enacted one or more laws which criminalize HIV transmission or exposure [16]. While specific laws and penalties differ widely from state to state, these laws typically require that PLWH disclose their serostatus to potential partners prior to engaging in sexual activities. In some states, even activities which pose a very low risk of transmission (e.g., cunnilingus, fellatio, mutual masturbation) are subject to criminal prosecution [17]. Evidence regarding the effectiveness of criminalization as a structural HIV prevention strategy is sparse. Studies conducted in Michigan [18], New Jersey [19], and Illinois [20] suggest that enacting HIV-specific transmission and exposure laws has not resulted in significant increases in disclosure or reductions in the rate of HIV transmission. Concerns remain that criminalization could actually result in increased risk of transmission. Disclosure laws may be perceived to shift the responsibility for safe sex to those who are HIV positive. This shift conflicts with public health messages which encourage all sexually active persons to be responsible for their own sexual health. The assumption that all potential partners who are HIV positive are aware of their serostatus and bound to disclose it could lead to a false sense of security and reduce self-protective behaviors. Criminalization of nondisclosure could also lead persons who suspect that they are positive to avoid having an HIV test, thus avoiding a positive diagnosis and the legal obligation to disclose [21]. Whether or not disclosure is required by law, however, efforts to evaluate the effectiveness of disclosure as a prevention strategy require the use of data and models which link disclosure to sexual behavior.

Recently, HIV researchers have been calling for the increased use of mathematical modeling approaches in a variety of HIV-related contexts [22, 23]. Generally, these models have been applied to situations where transmission rates vary among subgroups of interest (e.g., PLWH with acute vs. chronic HIV infection). The use of mathematical modeling has also been applied specifically to serostatus disclosure. Pinkerton and Galletly [8] introduced a mathematical framework for evaluating the effectiveness of serostatus disclosure as a strategy for the reduction of HIV transmission. Using published estimates of the prevalence of condom use and disclosure obtained from a variety of studies of HIV positive MSM sexual behavior, Pinkerton and Galletly demonstrated that increasing the rate of serostatus disclosure to 100 % could result in a 32.5–74 % reduction in the HIV transmission risk. Efforts to utilize these models are currently limited by available data on subgroups of interest which account for the effects of disclosure and seroadaptation on sexual risk behavior. At the time of publication, the authors noted that no published estimates of the rate at which MSM agree to anal intercourse after disclosure (i.e., the “agree to sex rate”) were available [8].

Purpose

The purpose of this work is to utilize the analytic framework proposed by Pinkerton and Galletly [8] to assess the effect of serostatus disclosure on the reduction of HIV transmission risk. The reduction in the rate of HIV transmission due to serostatus disclosure in this population is estimated, and direct estimates of the “agree to sex” rates, which to date had been unavailable, are provided. The model is then extended to incorporate the impact of one type of seroadaptation (i.e., serosorting) on disclosure effectiveness and provide empirical estimates of key parameters among discordant partners where the risk of HIV transmission is the highest.

Methods

Study Description, Data Collection, and Analysis

Data used in the analysis were collected between December 2009 and November 2011 at the baseline assessment of a longitudinal randomized-controlled trial of an intervention designed to assist HIV positive MSM in disclosing their serostatus to casual sex partners. Baseline data for the RCT included 164 participants recruited in a large Midwestern city. Recruitment for the study was accomplished through partnerships with local AIDS service organizations, cooperation with health practitioners, and marketing at HIV-related events. Participants in the study were all HIV positive, sexually active, MSM over the age of 18 who expressed an interest in learning about HIV disclosure. At baseline participants answered questions about their sexual encounters during the prior 30 days. Details of up to five encounters including partner serostatus (i.e., positive, negative, unknown), sexual activities (i.e., anal intercourse), condom use, and disclosure (i.e., prior to intercourse) were obtained using an author-derived instrument administered through audio computer-assisted self-interviewing (ACASI). Participants also provided self-reports of current viral load if known; they could also answer *don't know*, *undetectable*, or *never had a test*. Responses were then categorized into three levels; undetectable or <200, >200, or don't know/didn't have a test.

For the purpose of stimulating recollection and improving data reliability, a calendar was presented to the participants to assist them in identifying the dates of specific encounters. Data from the first reported encounter were used in this analysis. Therefore, only one encounter per participant was reported. Given the sensitive nature of these data, participant confidentiality was vigorously protected. All instruments, protocols, and procedures for maintaining confidentiality during data collection and storage were approved by the appropriate Institutional Review Board. All statistical computations were conducted using SPSSv21.

Measures of Sexual and Disclosure Behavior

A team of researchers with expertise in HIV prevention, psychometric assessment, and serostatus disclosure among MSM worked together to develop the measures used to assess participant sexual and disclosure behavior. Scale and item development was conducted in an iterative fashion, beginning with a review of measures used in prior studies and followed by a consensus-based process of editing and revision. Details of scale construction have been described elsewhere [24]. Items relevant to the current study include, “Did this encounter involve anal intercourse?”, “While you were the (top, bottom) did you always use a condom?”, and “Was this partner HIV positive?” Partners that were either reported to be HIV negative or of an unknown serostatus were considered serodiscordant. Disclosure in the encounter was coded based on participant responses to two items. First, participants were asked, “Did you disclose to your partner at this encounter (i.e., the day of the encounter?)”. Responses of “Yes” were coded as disclosures. When the participant responded “No” they were then asked the reason they had not disclosed at the encounter. If participants responded, “Because they already knew (i.e. I told them at least 1 day before the encounter),” the encounter was also coded as involving disclosure.

Mathematical Model for the Effect of Disclosure

Analyses began with the application of the mathematical model of HIV transmission risk as a function of disclosure proposed by Pinkerton and Galletly [8]. Similar to Pinkerton and Galletly, the following conventions for HIV transmission probabilities were used: $P(\text{transmission through unprotected intercourse}) = \alpha$; $P(\text{condom effectiveness at preventing HIV}) = \epsilon$; $P(\text{condom lack of effectiveness}) = 1 - \epsilon$; and $P(\text{transmission with condom use}) = (1 - \epsilon) * \alpha$. For clarity, the method used to estimate probability of HIV transmission with and without disclosure is shown in Fig. 1. Following along the branches of the tree diagram, conditional probability calculations show that an overall probability of transmission can be estimated from Eq. 1.

$$P(D, K, C) = DS(1 - \epsilon K)\alpha + (1 - D)(1 - \epsilon C)\alpha \quad (1)$$

As noted by Pinkerton and Galletly, $P(D, K, C)$ is the overall probability of HIV transmission as a function of the rate of disclosure (D), the rate of condom use during intercourse after disclosure (K), and the rate of condom use during intercourse without disclosure (C). The probability that the partners agree to have intercourse after disclosure (S) was estimated by Pinkerton and Galletly using a plausible range of 25–75 %. In our analysis,

(S) is computed directly from participant provided data. The first part of the expression on the right refers to risk of transmission with disclosure $S(1 - \varepsilon K)\alpha$; the second half refers to risk with no disclosure $(1 - \varepsilon C)\alpha$. The difference between these two risks—with and without disclosure—is the overall reduction attributed to disclosure, and the effectiveness of disclosure can be calculated by looking at *relative* reduction in risk (i.e., reduction divided by risk without disclosure); Pinkerton and Galletly refer to this as $E(K, C)$ (Eq. 2). Note the probability of transmission through unprotected intercourse (α) cancels from numerator and denominator when these risk estimates are compared, so that the relative reduction in transmission risk focuses only on S , K , and C .

$$E(K, C) = 1 - \frac{S(1 - \varepsilon K)}{(1 - \varepsilon C)} \quad (2)$$

Modeling the Effect of Disclosure with Serosorting

The mathematical model was extended by incorporating the effect of one type of seroadaptation (i.e., serosorting) on the risk of transmission. Since MSM can use serosorting as a risk reduction strategy whether or not they disclose, self-reported partner status was included in both the disclosure and nondisclosure branches of an adapted tree diagram (Fig. 2). In the figure, only the branches for serodiscordance (negative or unknown partner status) are extended to save space; the branches would be similarly extended for seroconcordance (positive partner status). For the purposes of this study, the effects of disclosure on the risk of HIV transmission associated with seroconcordant partners (i.e., the risk of super-infection) and serodiscordant partners (including partners of unknown status) were computed separately. Among serodiscordant partners, modified parameter estimates were obtained for the rates of agreement to intercourse after disclosure (S^*), condom use after disclosure (K^*), and condom use without disclosure (C^*). These are shown in Fig. 2. Modified estimates of the same parameters were also computed for seroconcordant partners (i.e., $S^\&$, $K^\&$, and $C^\&$). For each partner group (discordant and concordant), these modified estimates were then substituted into the formula for the relative risk reduction due to disclosure (Eq. 2) in order to model the effectiveness of disclosure in reducing HIV transmission rates.

Results

Demographics

Key demographic variables for the 164 participants contributing to the baseline analysis are shown in Table 1. While the average age of the participants was almost 40, participant age varied widely from 19 to 64. In terms of race and ethnicity, recruitment resulted in a sample that was almost equally divided between Caucasian (47 %) and African American (46 %). Hispanic MSM and those from other racial and ethnic groups comprised only 7 % of the sample. When compared with national data on the prevalence of HIV among MSM [24], minority participation was roughly proportionate. However, among minority participation, Hispanic MSM were underrepresented. The distribution of years since HIV diagnosis for the men in the sample is provided in Fig. 3. The median time since diagnosis was 7 years.

Twenty-nine participants (18 %) were diagnosed less than 1 year before enrolling in the study, and an additional 41 (25 %) had been diagnosed for less than 5 years.

Twenty-nine (18 %) participants reported a viral load greater than 200 and another 44 (27 %) reported that they didn't know their viral load, never had a viral load test, or declined to answer the question. The remaining participants ($n = 91$, 55 %) in the sample reported a viral load that was either undetectable or ≤ 200 . For those participants reporting a sexual encounter at baseline ($n = 144$), 40.3 % ($n = 58$) reported knowing their partner was also positive (seroconcordant), and 59.7 % ($n = 86$) indicated that their partner was negative or they were not aware of their partner's status (serodiscordant).

A series of Chi square tests of association were conducted to evaluate the role played by participants' self-reported viral load on sexual and disclosure behavior. No significant relationships were found between self-reported viral load and disclosure ($\chi^2(2) = 1.02$, $p = .60$), reported partner serostatus ($\chi^2(2) = .49$, $p = .78$), unprotected insertive anal intercourse ($\chi^2(2) = .23$, $p = .89$), or unprotected receptive anal intercourse ($\chi^2(2) = .66$, $p = .72$). Based on these results, viral load was not included in subsequent analyses.

Effect of Disclosure on HIV Transmission Risk

Of the 164 participants, only 144 men reported at least one sexual encounter at the baseline observation. Analysis was limited to this subset of participants. Of the 144 who reported a sexual encounter, 113 said they either disclosed or had sex with someone to whom they had previously disclosed, and 31 men did not disclose [$P(\text{disclosure}) = D = 78.5\%$]. Among the 113 men who disclosed, 79 men reported having intercourse [$P(\text{agrees to intercourse} | \text{disclosure}) = S = 69.9\%$]. Among the 31 men who did not disclose their status, 15 men reported having intercourse [$P(\text{agrees to intercourse} | \text{no disclosure}) = 48.4\%$]. Among the 79 men who had intercourse after disclosure, 56 men reported always using a condom [$P(\text{condom use} | \text{agreed to intercourse after disclosure}) = K = 70.9\%$]. Among the 15 non-disclosers engaging in intercourse, 9 reported using a condom [$P(\text{condom use} | \text{intercourse without disclosure}) = C = 60\%$]. These post-disclosure and non-disclosure condom use rates are somewhat lower than those used for illustration in Pinkerton et al.'s work. Their illustrations were based on $K = 77.6\%$ and $C = 72.7\%$ from Marks and Crepaz [12], and $K = 89.8$ and 76.6% from Niccolai et al. [13]. Using $\epsilon = .90$ from Pinkerton and Abramson [4], we find $E(K, C) = .450$. For our baseline data, the effectiveness of disclosure at reducing risk of transmission relative to non-disclosure is 45 %.

Impact of Serosorting

Next, the reduction in transmission risk due to disclosure adjusting for serosorting was computed. Disclosure effectiveness estimates were computed separately for serodiscordant ($n = 86$, 59.7 %) and seroconcordant ($n = 58$, 40.3 %) couples. Asterisks are used to signify parameter estimates among serodiscordant couples, and ampersands are used to signify parameter estimates among seroconcordant couples. Thus, two disclosure effectiveness estimates were computed and compared: $E(K^*, C^*)$ and $E(K^\&, C^\&)$. We retained the same estimate for condom effectiveness as the previous analysis, $\epsilon = .90$.

Among the 113 men who disclosed, 59 men (52.2 %) reported having a discordant partner (i.e., a partner believed to be HIV– or whose status was unknown). Forty of these men reported having intercourse [$P(\text{discordant partner agrees to intercourse}|\text{disclosure}) = S^* = 67.8 \%$]. Condom use was reported by 33 of these participants [$P(\text{condom use with discordant partner}|\text{intercourse after disclosure}) = K^* = 83 \%$]. Among the 31 men who did not disclose their status, 27 men (87 %) reported having a serodiscordant partner (i.e., partner was negative or unknown status). Thirteen of these reported having intercourse [$P(\text{discordant partner agrees to intercourse}|\text{no disclosure}) = 48.1 \%$] and 8 of these men reported condom use [$P(\text{condom use with discordant partner}|\text{intercourse without disclosure}) = C^* = 62 \%$]. Among serodiscordant partners, $E(K^*, C^*) = .612$ (Eq. 2) and the effectiveness of disclosure at reducing risk of transmission relative to nondisclosure is 61.2 %.

Similarly, we computed the relevant parameter estimates for the self-reported seroconcordant couples and mark these estimates with an ampersand. Among the 113 participants who disclosed, 54 indicated they were seroconcordant. Of these couples, the “agree to sex” rate after disclosure ($S^\& = 72.2 \%$) was higher than among the serodiscordant couples ($S^* = 67.8 \%$). We also found that the rates of condom use with disclosure ($K^\& = 59 \%$) and without disclosure ($C^\& = 50 \%$) were more similar to each other but lower than the respective condom use estimates among serodiscordant partners ($K^* = 83 \%$, $C^* = 62 \%$). As a result, the reduction in risk due to disclosure was lower for participants with a seroconcordant partner, $E(K^\&, C^\&) = 38.4 \%$.

Though transmission of the HIV virus is still possible between HIV positive and concordant partners (i.e., superinfection), it is generally accepted that the risk of this type of HIV transmission is much lower. Therefore, this proportional reduction in transmission applies to a much lower base rate of transmission.

Discussion

Using baseline data from a study of disclosure in HIV positive MSM, the mathematical framework proposed by Pinkerton and Galletly [8] was applied to estimate the HIV transmission risk reduction effectiveness of serostatus disclosure. This approach makes it possible to connect changes in sexual behavior (i.e., increased condom use, avoidance of anal intercourse) resulting from disclosure to reductions in the risk of HIV transmission. In sexual encounters involving disclosure, a 45 % reduction in the risk of HIV transmission was observed over encounters where disclosure did not occur. Estimates obtained in this study provide further evidence of the effectiveness of serostatus disclosure as a risk reduction strategy, and support the need for evidence-based interventions which increase disclosure of serostatus to sexual partners.

After extending the mathematical model to adjust for knowledge of partner's serostatus, the estimate of disclosure effectiveness was higher for participants who knew their partner was negative or were unaware of the partner's status. Among discordant couples, disclosure resulted in a 61.2 % reduction in the risk of HIV transmission. This was due to the increase in the rate of condom use with disclosure (K^*) among discordant couples. The effectiveness

of disclosure was much lower in seroconcordant couples, at 38.4 %. This lower relative risk reduction estimate was largely due to the similarity in the condom use rates with ($K^{\&} = 59\%$) and without ($C^{\&} = 50\%$) disclosure in concordant couples (both positive). The fact that risk reduction is stronger within discordant couples is particularly encouraging because of the far greater risk of HIV transmission associated with discordant anal intercourse. It is important to note that these proportional reduction estimates are in reference to different base rates of HIV transmission risk. Note that the base rate of transmission (i.e., $P(\text{transmission through unprotected intercourse}) = \alpha$) “cancels out” in the Pinkerton and Galletly [8] framework, which provides a mathematical advantage in estimating proportional risk reduction but also represents a challenge for the interpretation of differences in the risk reduction rate.

Disregarding serostatus, parameter estimates obtained for condom use with ($K = 70.9\%$) and without ($C = 60\%$) disclosure were similar to those obtained by Marks and Crepaz [12] and Niccolai et al. [13]. However, the base rate (i.e., pre-intervention) of disclosure ($D = 78.5\%$) obtained in our sample was higher than was observed by Marks and Crepaz [12]. This could be due to the relatively large proportion of participants (23 %) in our sample who reported being in monogamous relationships. Research on HIV positive MSM has suggested that those in committed relationships may be more likely to have disclosed [25] and to engage in unprotected anal intercourse [26]. Care should be taken when generalizing baseline estimates of disclosure (D), condom use with disclosure (K), and the “agree to sex” rates (S) obtained in this analysis to other populations. It is interesting to note, however, that higher “agree to sex” rates (S) and lower condom use rates with disclosure (K) both result in lower estimates of disclosure effectiveness [8].

While the results of this study provide additional evidence of the effectiveness of serostatus disclosure as a strategy for reduction in HIV transmission risk, some limitations are present. First, the data used in these analyses were obtained from a relative small sample of volunteers. Parameter estimates in larger samples, and across a variety of subpopulations, are necessary in order to better estimate the impact of increased disclosure on HIV transmission. The participants varied in age and time since diagnosis, but the limited sample size made it impossible to adequately explore potential related behavioral variation which could confound the estimation of disclosure effectiveness. The use of only one sexual encounter per participant was also a limiting factor in the ability to model disclosure effects. Extensions of this approach to accommodate multiple and varied behaviors within individuals are needed. It is also important to note that, while disclosure can result in the use of seroadaptive strategies (i.e., withdrawal, seropositioning, condom use), HIV positive MSM might also adapt their behavior as a way of avoiding the need to disclose. Our model is limited in that it estimates the effect of disclosure controlling for self-reported serosorting, but not the potential effect of serosorting on disclosure. Further work is needed to determine the extent to which disclosure is affected by serosorting and other seroadaptive strategies. Finally, new research has underscored the importance of HAART adherence and viral load to HIV transmission. While this study was limited to an evaluation of the relative reduction in HIV transmission risk due to disclosure, future disclosure studies including reliable data on viral load are needed to improve our understanding of the relationship between disclosure, adherence, and HIV risk reduction. Despite these limitations, the results of this

study confirm the importance of disclosure as a risk reduction behavior. HIV prevention for HIV+ MSM should include interventions designed to assist HIV+ persons with serostatus disclosure.

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Fig. 1.
Tree diagram for HIV transmission for disclosure groups

Fig. 2.

Tree diagram for HIV transmission for disclosure groups with serosorting, serodiscordant/unknown couples only

Fig. 3.
Participant time since diagnosis as HIV positive (N = 164)

Table 1Participant demographic characteristics ($N = 164$)

	M	SD
Participant age	39.5	11.2
	n	%
Race/ethnicity		
African American	75	46
Caucasian	77	47
Other/mixed	12	7
Sex partners		
Only men	120	73
Mostly men	26	16
Men and women	15	9
Mostly women	3	2
Sexual identification		
Gay	126	77
Bisexual	37	23
Heterosexual	1	1
Relationship status		
Single	109	66
Committed/partnered (monogamous)	37	23
Committed/partners (non-monogamous)	18	11
Reported sexual encounters (max. 5)		
0 encounters	20	12
1 encounter	18	11
2 encounters	24	15
3 encounters	22	13
4 encounters	9	6
5 encounters	71	43