Appendix

A mathematical model was developed to estimate the relationship between the proportion of the HIV-infected population that is undiagnosed and the relative risk per contact of unprotected anal intercourse (UAI); acts where condoms are used were not considered because the majority of transmissions occur due to UAI. The model was formulated as follows.

If serosorting does not occur then each casual partnership formed with an HIV-uninfected MSM has average probability of being serodiscordant represented by the following mathematical expression:

$$Q_{serosort} = (N_{ND}+N_D+N_T)/(N_S+N_{ND}+N_D+N_T). \quad (1)$$

Here N_S, N_{ND}, N_D, and N_T represent the number of HIV-uninfected MSM who are potentially susceptible to infection, HIV-infected MSM who are not diagnosed and thus unaware of their serostatus, HIV-infected MSM who have been diagnosed with their infection, and MSM who are on antiretroviral therapy (ART) for their known HIV infection, respectively. If serosorting does occur and false disclosure does not occur then each new partnership has average probability of being discordant given by:

$$Q_{no\ serosort} = N_{ND}/(N_S+N_{ND}). \quad (2)$$

Average transmission probabilities per serodiscordant act of UAI with a casual partner who is undiagnosed (β_{ND}), diagnosed but untreated (β_D), and on ART (β_T), can be estimated as weighted averages based on the proportion of acts that are insertive, receptive with withdrawal, or receptive with ejaculation, according to the perceived HIV status of the partner. We use detailed behavioral data from the Health in Men (HIM) cohort [1,2], a highly studied cohort of gay men, to inform these estimates (see Fig. 1a). For example, based on the HIM study [2], if a partner's HIV status is unknown then an average of q_i^U =46% of UAI acts are likely to be insertive, q_{rw}^U =33% are likely to be receptive but with withdrawal prior to ejaculation, and q_r^U =21% are likely to be receptive with ejaculation (Fig.

A1). Then, the average risk of HIV transmission per serodiscordant act of UAI with a partner whose serostatus is unknown is given by

$$\beta_U = q_i^U \beta_i + q_{rw}^U \beta_{rw} + q_r^U \beta_r \,, \tag{3}$$

yielding a value of ~0.0032, where the respective transmission probabilities are taken to be β_i =0.001, β_{rw} =0.002, and β_r =0.010 [3,4].

Similarly, the risks per contact with a partner of known HIV infection, based on the change in sexual positioning (Fig. 1a), are given by

$$\beta_D = q_i^D \beta_i + q_{rw}^D \beta_{rw} + q_r^D \beta_r \,, \tag{4}$$

yielding a value of ~0.0023 and

$$\beta_T = \left(1-\phi\right) \beta_D \,, \tag{5}$$

yielding a value of ~0.0001, where $\phi = 0.95$ is the estimated reduction in infectiousness due to effective treatment [4].

The average HIV transmission probability per act of UAI with a partner who is HIV-positive but is not aware of his infection is given by

$$\beta_{ND} = q_i^N \beta_i + q_{rw}^N \beta_{rw} + q_r^N \beta_r \,, \tag{6}$$

yielding a value of ~0.0069, which is considerably greater than the risk of UAI with partners of any other perceived HIV status.

We do not consider different infectiousness periods during the natural history of infection but use estimates from the chronic asymptomatic stage of infection (ignoring the greater infectiousness of newly acquired infections) [3,5].

We estimate the relative risks of HIV acquisition associated with serosorting compared with not serosorting and refer to this as the relative risk of serosorting. For serosorting, if HIV status is disclosed then partnerships where UAI takes place will only form if the partner is thought to be seroconcordant and the sexual positioning (insertive or receptive UAI with or without ejaculation) within the partnership is then based on perceived knowledge of the partner's serological concordance (Fig. A1). In comparison, if serosorting does not occur a sexual partnership may form regardless of the partner's serostatus and sexual positioning within the partnership is more conservative (Fig. A1). Accordingly, if the prevalence of HIV in the population is P, p_{ND} is the proportion of HIV-infected MSM that are not diagnosed, and p_T is the proportion of HIV-infected MSM who are diagnosed that are on treatment, then

$$N_S = N(1-P),\ N_{ND} = NPp_{ND},\ N_D = NP(1-p_{ND})(1-p_T),\ N_T = NP(1-p_{ND})p_T, \quad (7)$$

and the relative risk of serosorting compared with not serosorting can be represented mathematically by the ratio of the chance of transmission when serosorting to the chance of transmission when not serosorting, namely,

$$\rho = \beta_{ND} p_{ND} \Big/ \left[(1-P+Pp_{ND})\left(\beta_U p_{ND} + \beta_U (1-p_{ND})(1-p_T) + \beta_U p_T (1-\phi)(1-p_{ND})\right)\right]. \quad (8)$$

This relative risk has maximum value (when there is no HIV testing) of

$$\rho_{\max} = \frac{q_i^N \beta_i + q_{rw}^N \beta_{rw} + q_r^N \beta_r}{q_i^U \beta_i + q_{rw}^U \beta_{rw} + q_r^U \beta_r}, \quad (9)$$

yielding a value of ~2.15, and a minimum value (when everyone knows their true HIV status) of $\rho_{\min} = 0$.

References for Appendix

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