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# Modelling the Impact of HIV Disease on Mortality in Gay and Bisexual Men

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Hogg R S ( British Columbia Centre for Excellence in HIV/AIDS, St Paul's Hospital, 608–1081 Burrard Street, Vancouver, BC, Canada, V6Z 1Y6), Strathdee S A, Craib K J P, O'Shaughnessy M V, Montaner J S G and Schechter M T. Modelling the impact of HIV disease on mortality in gay and bisexual men. *International Journal of Epidemiology* 1997; **26:** 657–661.
*Objective.* To assess how HIV infection and AIDS (HIV/AIDS) impacts on mortality rates for gay and bisexual men.
*Methods.* Vital statistics data were obtained for a large Canadian urban centre from 1987 to 1992. Three scenarios were utilized with assumed proportions of gay and bisexual men of 3%, 6% and 9% among the male population age ⩾20 years. For each scenario, non-HIV deaths were distributed according to the assumed proportion of the total population (3%, 6% or 9%), but 95% of HIV deaths were distributed to gay and bisexual men as this is the proportion of AIDS cases in gay and bisexual men in this centre. The main outcome measures of interest were age-specific patterns of death, life expectancy and life expectancy lost due to HIV/AIDS at exact age 20 years, and the probability of living from age 20 to 65 years.
*Results.* Estimates of the mid-period gay and bisexual population ranged from 5406 to 16 219 for the three scenarios, and total deaths in these men from 953 to 1703. Age-specific mortality was significantly higher for gay and bisexual men than all men aged 30–44. Life expectancy at age 20 for gay and bisexual men ranged from 34.0 years to 46.3 years for the 3% and 9% scenarios respectively. These were all lower than the 54.3 year life expectancy at age 20 for all men. The probability of living from age 20 to 65 years for gay and bisexual men ranged from 32% for the 3% scenario, to 59% for the 9% scenario. These figures were considerably lower than for all men where the probability of living from 20 to 65 was 78%.
*Conclusion.* In a major Canadian centre, life expectancy at age 20 years for gay and bisexual men is 8 to 20 years less than for all men. If the same pattern of mortality were to continue, we estimate that nearly half of gay and bisexual men currently aged 20 years will not reach their 65th birthday. Under even the most liberal assumptions, gay and bisexual men in this urban centre are now experiencing a life expectancy similar to that experienced by all men in Canada in the year 1871.
*Keywords*: HIV infection, mortality, survivorship, homosexual men, bisexual men

HIV infection and AIDS (HIV/AIDS) continues to have a profound effect on death rates worldwide. In developed countries, HIV/AIDS is now the leading underlying cause of death among middle-aged men in many geographical regions and urban centres. In the US, recent research has identified HIV/AIDS as the leading cause of death among men aged 25–44 in the states of New York, New Jersey, California, Florida, and Massachusetts, and 64 out of 170 cities having reported at least 25 AIDS-related deaths.[1] Similarly, in Europe and Canada HIV/AIDS is now the leading cause of death in middle-aged men in several urban centres.[2–4] Deaths attributable to HIV have led to an enormous burden on adult and childhood mortality in developing areas of the globe, such as sub-Saharan Africa.[5,6]

Data on the impact of HIV/AIDS on mortality in populations most at risk, such as gay and bisexual men, injection drug users, and haemophiliacs, are very limited and methods used to assess these trends are problematic.[7,8] While surveillance systems in most developed countries report AIDS cases or deaths according to behavioural exposure categories, rates cannot be calculated without estimates of the population who engage in these behaviours. The scarcity of such essential data derives from the social sanctions frequently applied to sexual and drug use behaviour. This decreases the likelihood that individuals at risk can be identified through social surveys and the probability that current administrative databases will obtain reliable, accurate information on sexual orientation or drug use. Nevertheless, there is a need for accurate data on the demographic impact of HIV/AIDS in these groups and for imaginative strategies for conducting such research activities. In this article we describe such an approach to examine the impact of HIV/AIDS on mortality in gay and bisexual men.

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## METHODS

Our analysis is based on a demographic model of male mortality and life expectancy in the city of Vancouver, British Columbia. This urban centre, part of the third largest metropolitan population in Canada, was selected because it is known to have a large gay and bisexual population and one of the highest rates of HIV/AIDS mortality of any Canadian city.[2,3] In this city, HIV/AIDS is the leading cause of death in men between the ages of 25 and 39 years and the leading cause of premature mortality in men before age 75 years.[2]

A demographic approach was used to simulate the impact of HIV/AIDS on the age-specific mortality and life expectancy of gay and bisexual men and all men in Vancouver for the period 1987 through 1992. Three scenarios for gay and bisexual men were modelled based on varying assumptions relating to population size. Gay and bisexual men were assumed to account for either 3, 6 or 9% of the total male population aged ⩾20 years. The lower-bound limit is derived from estimates for the prevalence of men who have sex with men in a given year, while the upper-bound coincides with liberal estimates for lifetime history of same gender sex.[9–11] These three proportions were judged to encompass both the most conservative and liberal estimates for the proportion of gay and bisexual men among the adult male population.

The values assigned to model parameters were based, where possible, on empirical data. Mid-period population estimates, broken down by 5-year age groups, were based on intercensal estimates computed from the 1986 and 1991 censuses.[12,13] Estimates of the number of deaths, by 5-year age group and major cause, were based on vital statistics data from the British Columbia Division of Vital Statistics. Known non-HIV deaths were distributed by 5-year age group according to the proportion of the total population that gay and bisexual men were assumed to represent. The number of known deaths attributable to HIV remained fixed for each scenario of gay and bisexual men. Based on the current evidence of reported AIDS cases in gay and bisexual men in this centre, we estimated *a priori* that gay and bisexual men accounted for 95% of known deaths due to HIV/AIDS in this study period.[14]

Model-derived patterns of mortality and life expectancy were assessed using a variety of demographic methods. First, abridged period life tables were constructed to compare patterns of age-specific mortality, life expectancy at exact age 20 years, survivorship and probability of living from exact age 20 to 65 years.[15,16] These tables were used to characterize the mortality experience that a hypothetical cohort of men would have if it was subjected to the mortality rates in a given population scenario over the 6-year study period. Second, cause-deleted life tables were constructed to compare the impact on life expectancy after deaths attributable to HIV/AIDS were removed. Computation steps for cause-deleted tables are similar to that for abridged life tables, except that the former also take into account the effects of competing risks on patterns of cause-specific mortality.[17] Standard errors for life expectancy values for both life tables were computed using methods previously described in the literature.[12]

TABLE 1 *Population and deaths for gay and bisexual and all men aged ⩾20 years in Vancouver, 1987–1992*

| | Mid-period population | Proportion of total deaths attributable to HIV/AIDS[a] | Total number of deaths |
|---|---|---|---|
| Gay and bisexual men | | | |
| 3% of population | 5406 | 0.61 | 953 |
| 6% of population | 10 813 | 0.44 | 1328 |
| 9% of population | 16 219 | 0.34 | 1703 |
| All men | 180 215 | 0.05 | 13 106 |

[a] A total of 609 HIV/AIDS deaths were observed in Vancouver from 1987 to 1992. The number of HIV/AIDS deaths in the three model derived scenarios remained fixed at 579 deaths or 95% of deaths in total male population attributable to HIV/AIDS.

## RESULTS

Based on census and vital statistics data, the mid-period Vancouver male population was estimated to be 180 215 and the total number of male deaths in Vancouver from 1987 to 1992 was observed to be 13 106, of which 609 or 5% were attributable to HIV/AIDS either as the underlying or antecedent cause of death. Under the three model-derived scenarios estimates of the mid-period gay and bisexual population aged ⩾20 years in Vancouver ranged from 5406 to 16 219 and estimates of the total deaths ranged from 953 to 1703. The number of HIV/AIDS deaths in the three scenarios remained fixed at 579 deaths or 95% of all deaths in the total male population attributable to HIV/AIDS (Table 1).

Figure 1 compares patterns of age-specific HIV/AIDS mortality rates for gay and bisexual and all men aged 20–64 years. Rates of age-specific mortality were highest for gay and bisexual men, with rate differentials between gay and bisexual and all men increasing as the modelled proportion of gay and bisexual men in the total male population decreased. For example, the mortality rate per 100 000 population for all men age

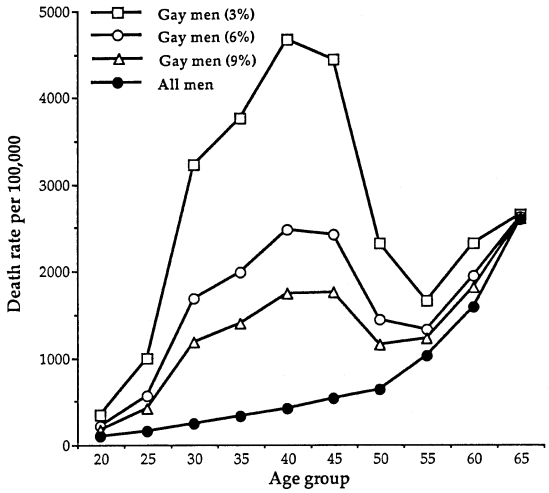


FIGURE 1 *Age-specific HIV/AIDS mortality rates for gay and bisexual and all men aged 20–64 years in Vancouver, 1987–1992*

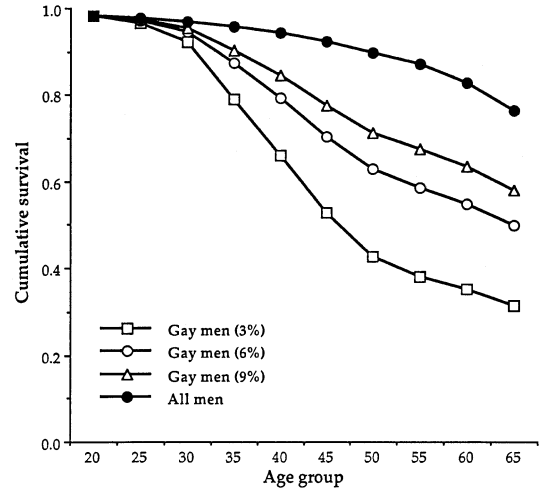


FIGURE 2 *Survivorship of gay and bisexual and all men aged 20–64 years in Vancouver, 1987–1992*

40–44 was 414, while the mortality rate in gay and bisexual men aged 40–44 under the 3% assumption was as high as 4665. In all three scenarios for gay and bisexual men, the maximal mortality occurred from the ages of 30–44 years. In contrast, mortality rates for all men combined demonstrated the conventional relationship between age and mortality. The slopes for the three scenarios of gay and bisexual men and all men combined starting converging from age 55 years onward.

Figure 2 depicts the survivorship of gay and bisexual and all men during the age interval of 20–69 years. As seen here, the probability of surviving during this age interval was lowest under the scenario in which gay and bisexual men represent 3% of the total male population and highest for all men. The probability of surviving from exact age 20 to 65 years for gay and bisexual men ranged from 0.32 to 0.59 for the three scenarios, where the lowest probability was observed when gay and bisexual men represent 3% of the total population. For all men, the probability of living during the same interval was 0.78.

Table 2 compares the life expectancy and loss in expectation of life attributable to HIV/AIDS at age 20 years for gay and bisexual men versus all men. Life expectancy at age 20 for gay and bisexual men ranged from 34.0 to 46.3 years for the three scenarios. The lowest figure was for the 3% scenario and highest when 9% of the total male population was assumed to be gay and bisexual. Figures for all three scenarios of gay and bisexual men were considerably lower than the life expectancy for all men of 54.3 years. The loss in life expectancy due to HIV/AIDS for gay and bisexual men ranged from 21.3 years to 9.0 years for the 3% and 9% scenarios respectively. In contrast, loss in life expectancy attributable to HIV/AIDS for all men was one year.

TABLE 2 *Life expectancy and loss in expectation of life attributable to HIV/AIDS at exact age 20 years for gay and bisexual and all men in Vancouver, 1987–1992*

| Population | Life expectancy[a] | Loss in expectation of life due to HIV/AIDS[a] |
|---|---|---|
| Gay and bisexual men | | |
| 3% of population | 34.0 (0.7) | 21.3 (0.9) |
| 6% of population | 42.6 (0.5) | 12.7 (0.7) |
| 9% of population | 46.3 (0.4) | 9.0 (0.6) |
| All men | 54.3 (0.1) | 1.0 (0.2) |

[a] Standard errors around each value are shown in parentheses.

## DISCUSSION

In mid-1989, we estimate there were from 5406 to 16 219 gay and bisexual men living in the city of Vancouver based on prevalences ranging from 3% to 9%. Even if our most liberal assumption of 9% applied, Vancouver gay and bisexual men would still be experiencing a life expectancy similar to that endured by Canadian men in the year 1871.[18] At that time, men aged 20 years could

expect to live another 48 years of life. Under the 9% scenario, gay and bisexual men at age 20 can expect to live another 46 years and have a total life span of 66 years in this major urban centre. Approximately 42% of gay and bisexual men under this mortality regime would die before age 65 with the maximal mortality occurring between the ages of 30 and 44 years.

Our model-derived age-specific patterns of mortality concur with other recent studies which have examined the mortality experience of populations most at risk of HIV infection. Among gay and bisexual men, data from the San Francisco City Clinic cohort indicate that HIV infection is the leading underlying cause of death.[19] As early as 1987, the age-adjusted mortality rate for HIV infection (ICD-9 042–044) in this cohort was 154 times (95% CI : 131–179) the expected rate if mortality rates for the total US male population are applied. Among haemophiliacs, multiple-cause of death data for the US indicate that the number of deaths at most ages have increased substantially from 1968 to 1989.[20] These age-specific increases were most marked in association with deaths from HIV infection. The proportion of deaths attributable to HIV/AIDS has risen from 20% in 1983–1985 to 55% in 1987–1989.

There are a number of methodological limitations inherent in this analysis. First, although we have revealed that the life expectancy of gay and bisexual men has sustained a tremendous deficit relative to all men, the true effect is likely to be larger because of problems of underreporting and underdiagnosis of AIDS. In Canada, cases of AIDS have been shown to be underestimated in the national registry by approximately 15–20%.[21] This level of underreporting of AIDS cases is not unique to Canada and reflects a common problem found throughout the developed world.[22] If, in our analysis, the extent of underreporting of deaths attributable to AIDS is greater than that of other major causes of death, as appears likely, then the relative impact of HIV/AIDS compared with other diseases will have been underestimated.

Second, the pattern of non-HIV mortality for gay and bisexual men may be distinctly different from that exhibited by all men. This is unlikely to be the case for most causes of death. For example, mortality data from the San Francisco City Clinic cohort has revealed that only HIV infection and suicide have a higher than expected rate of death. In the case of deaths from suicide, gay and bisexual men in the latter cohort were 3.4 times (95% CI : 1.1–7.9) more likely in 1987 to die from this cause than the total US male population.[19] Clearly, if there are other causes of mortality which are higher in gay and bisexual men, then the net effect is that we will have underestimated the true deficit in life expectancy being experienced by this population.

Despite these shortcomings, we believe our methodology offers a strategy for quickly and simply measuring the impact of HIV/AIDS on populations most at risk of acquiring HIV. Most importantly, this indirect estimation procedure addresses many of the shortcomings inherent with available vital event and census data sources. Further, it does not require considerable effort or time to describe demographic parameters of hard to reach populations most at risk nor is it limited to simulating patterns of mortality at national or pan-national level. Overall, we hope that our methodological approach will stimulate further research in this area and provide important insights into the mortality experiences of populations most affected by HIV/AIDS.

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## REFERENCES

[1] Selik R M, Chu S Y, Buehler J W. HIV infection as leading cause of death among young adults in US cities and States. *JAMA* 1993; **269:** 2991–94.

[2] Hogg R S, Schechter M T, Montaner J S G, Goldstone I, Craib K, O'Shaughnessy M V. Impact of HIV infection and AIDS on deaths rates in British Columbia and Canada. *Can Med Assoc J* 1994; **150:** 711–17.

[3] Hogg R S, Heath K U, Strathdee S A, Montaner J S G, O'Shaughnessy M V, Schechter M T. HIV/AIDS mortality in Canada: evidence of gender, regional and local area differentials. *AIDS* 1996; **10:** 889–94.

[4] Bindels P J E, Reeijneveld S A, Mulder-Folkerts D K F, Coutinho R A, van den Hoek A J A R. Impact of AIDS on premature mortality in Amsterdam, 1982–1992. *AIDS* 1994; **8:** 233–37.

[5] Mulder D W, Nunn A J, Wagner H-U, Kamali A, Kengeya-Kayondo J. HIV-1 incidence and HIV-1 associated mortality in a rural Ugandan population cohort. *AIDS* 1994; **8:** 87–92.

[6] Nicoll A, Timæus I, Kigadye R-M, Walraven G, Killewo J. The impact of HIV-1 infection on mortality in children under 5 years of age in sub-Saharan Africa: a demographic and epidemiologic analysis. *AIDS* 1994; **8:** 995–1005.

[7] Boulton M. Methodological issues in HIV/AIDS social research: recent debates, recent developments. *AIDS* 1993; **7 (Suppl. 1):** S249–55.

[8] Gibbs D A, Hamill D N, Magruder-Habib K. Populations at increased risk of HIV infection: current knowledge

and limitations. *J Acquir Immune Defic Syndr* 1991; **4:** 881–89.

[9] Michael R T, Laumann E O, Gagnon J H, Smith T W. Number of sex partners and potential risk of sexual exposure to human immunodeficiency virus. *MMWR* 1988; **37:** 565–68.

[10] Fay R E, Turner C F, Klassen A D, Gagnon J H. Prevalence and patterns of same gender sexual contact among men. *Science* 1989; **243:** 338–43.

[11] Rogers S M, Turner C F. Male-male sexual contact in the USA: findings from five sample surveys, 1970–1990. *J Sex Res* 1991; **28:** 491–519.

[12] Statistics Canada. Profile of census division and subdivisions in British Columbia—Part A. Ottawa: Statistics Canada, 1992.

[13] Statistics Canada. Profile of census division and subdivisions in British Columbia—Part 1. Ottawa: Statistics Canada, 1992.

[14] Rekart M L, Roy J N. AIDS update quarterly report. Second Quarter 1994. Vancouver: British Columbia Centre for Disease Control, Ministry of Health and Ministry Responsible for Seniors, 1994.

[15] Chiang C L. *The Life Table and its Applications*. Malabar: Robert E Krieger Publishing Company, 1984.

[1] Hsieh J J. Construction of expanded continuous life tables—a generalization of abridged and complete life tables. *Math Biosci* 1991; **103:** 287–302.

[17] Keyfitz N, Frauenthal J. An improved life table method. *Biometrics* 1975; **31:** 889–99.

[18] Statistics Canada. Historical statistics of Canada, 2nd edition. Ottawa: Ministry of Supply and Services, 1983.

[19] Hessol N A, Buchbinder S P, Colbert D *et al*. Impact of HIV infection on mortality and accuracy of AIDS reporting on death certificates. *Am J Public Health* 1992; **82:** 561–64.

[20] Chorba T L, Holman R C, Strine T W, Clarke M J, Evatt B L. Changes in longevity and causes of death among persons with hemophilia A. *Am J Hematol* 1994; **45:** 112–21.

[21] Calzavara L M, Coates R A, Craib K J P *et al*. Underreporting of AIDS cases in Canada: a record linkage study. *Can Med Assoc J* 1990; **142:** 36–39.

[22] Gertig D M, Marion S A, Schechter M T. Estimating the extent of underreporting in AIDS surveillance: a review. *AIDS* 1991; **5:** 1157–64.

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