John Newmeyer
Haight-Ashbury Free
Medical Clinic
February 3, 1987

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A Model of AIDS Exposure, Transmission, and Morbidity Among Gay Male San Franciscans

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It is well established that AIDS results from infection by the HTLV-III (a.k.a. LAV) virus, and, further, that infection has heretofore been largely confined to specific groups who were infected because of particular invasive practices. In San Francisco, more than 98% of AIDS cases have occurred among gay men. These men engaged in behaviors, such as anal and oral intercourse, which permitted invasion of the virus from infected partners.

The AIDS epidemic among gay male San Franciscans, therefore, seems an ideal subject for the development of a general model of AIDS transmission and morbidity. To construct such a model, three parameters are required:

(1) The total population of gay males in San Francisco.

(2) The rate, by six-month periods, of HTLV-III seroconversion among gay male San Franciscans.

(3) The rate, by six-month periods, at which seropositive gay men are diagnosed with AIDS.

In order to compare the model's predictions with observed data, a fourth parameter is needed:

(4) The incidence of AIDS diagnoses in San Francisco, among gay men who are residents of that city.

To examine AIDS exposure and relate it to consequent transmission of HTLV-III ("infection"), two further parameters are necessary:

(5) The incidence of various invasive sexual practices among gay male San Franciscans, at different periods.

(6) The probability, for each of those periods, that the sexual practice will involve an uninfected male mating with an infected male.

The soundest estimate for parameter (1) is the market research study conducted by Research and Decisions Corporation in 1984.

This study concluded that the resident gay male population was 70,000. Other estimates have generally been higher-- some as high as 150,000-- but they are hard to credit, particularly in view of 1980 census figures showing a total of only 133,000 single males aged 15 or more. The author believes that even the 70,000 estimate is accurate only if octogenarians, celibates, young men still "in the closet", and other "inactive" categories are included. The number of sexually active gay male San Franciscans, he believes, could be as low as 40,000. However, the Research and Decisions estimate will be retained for the purposes of this analysis.

Parameter (2) was estimated by working backward from certain points in time for which the "cumulative seropositive" rate was known. Preliminary data from the Men's Health Study indicate that, at the end of 1985, about 45% of gay men in San Francisco were seropositive. Data from the Alternative Test Sites show that about 30% of the gay men seen by them tested positive, in late 1985. A retesting of frozen blood samples from gay men in the Hepatitis Study indicated a steady rise in seropositivity, from 1% in 1978 to 64% in 1984. Other samples of the city's gay men showed seropositivity rates between these extremes. All of these surveys are hampered by bias in the sampling procedure: the Men's Health Study underrepresents men from the (presumably less promiscuous) gay population of the southern and western parts of the city; the Hepatitis Study drew from the (presumably very promiscuous) clientele of the city's V.D. clinics; and the Alternative Test Sites seem to be drawing proportionally fewer gay men who are "afraid of obtaining a 'positive' test result." The author weighed all these survey results, and their likely biases, to arrive at "cumulative seropositive" percentages of the total gay male population for the ends of 1981, 1983, and 1985 (see Table 1). He then used another preliminary estimate-- also from the Men's Health Study-- that some 5% more of gay males seroconverted in the year prior to Fall 1985. Finally, he assumed that the seroconversion curve had a smooth form, rising from near zero in 1978 to a peak in late 1982 and declining thereafter.[1] Putting this all together with the estimate of 70,000 gay males yielded the estimates of the actual "number seroconverting" by six-month periods, shown in the second column of Table 1.

Estimates for parameter (3) were developed by combining information from a large number of research reports touching upon the issue of diagnosis as a function of time after infection. The work of James Goedert et al (Science, 28 February 1986, pp. 991-995) is typical of these reports. Again, the author used a weighted judgment of the validity of these studies, and an assumption of smoothness of the curve of diagnosis rates v. time after infection, to arrive at the estimates shown in Table 2.

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1 The notion that gay male seroconversion declined significantly in recent years is supported by data from David Ostrow's research group in Chicago. Their prospective study of Midwestern gay mean suggests that seroconversion rates were about 8% per annum as of late 1984, but only about 2 to 3½% in late 1985.

Table 2 indicates that AIDS diagnosis rates among infected persons are zero in the first half-year after infection, and rise steeply to a peak rate in the third year. A gradual decline takes place thereafter, resulting in a cumulative diagnosis rate of 10.5% after five years, and 20.5% after ten years. There is very little data, as yet, to indicate the fate of individuals in the sixth and subsequent years following HTLV-III infection. However, it now seems unlikely that there is any sort of "all clear" signal after the fifth year; this hope was a major factor in early, perhaps optimistic, judgments about the virus' "incubation period". The author believes it is more likely that AIDS infection behaves much like certain forms of lethal cancers, from which (P) percent of those stricken will eventually die (if something else doesn't kill them first) and from which (100-P) percent will recover completely. He believes a P of 40% morbidity, and mean diagnosis delay of about ten years, most accurately fits the observed morbidity curve for the AIDS virus. Apparently, nearly all of those stricken with AIDS will die, with a life expectancy of about 18 months; but future developments in treatment could easily change this grim prognosis that "morbidity = mortality".

It is a simple matter to combine parameters (1), (2), and (3) to develop predictions as to the incidence of AIDS morbidity among each of the "infection cohorts" of gay male San Franciscans. For simplicity, each six-month cohort is assumed to have been infected on the first day of the six-month period. Table 3 shows the result of these calculations. The columns on the left side of the Table show the period for each cohort, and the number of men involved. Each row shows the predicted number of AIDS diagnoses from each cohort, by six-month periods. The sum of each column then gives the predicted morbidity for the half-year in question (due to rounding, the totals shown are sometimes slightly different from the totals obtained by adding the columns.)

To provide data for "observed morbidity" to compare to the figures predicted in the model, it is necessary to adjust the morbidity data provided by the San Francisco Department of Health in two ways. First, the cases who are not gay males must be discounted; and second, the cases who are gay men, but not San Francisco residents, must be removed. Some 2% of the city's cases are not gay males, and, according to Dr. Dean Echenberg, approximately 11% of the caseload consists of persons newly migrated to San Francisco, attracted by the manifestly superior treatment the city provides for a person with an AIDS or "pre-AIDS" condition.

The corrected figures for observed morbidity are shown in the bottom row of Table 3. Graph 1 displays the relation between the predicted and observed data. The fit between the two curves is excellent, through the end of 1985. The model predicts that morbidity rates will continue to rise, albeit very slowly, through 1987, and then remain level through 1989.

Based on the model, and on the observation that gay men diagnosed with AIDS have a life expectancy of 18 months, one can

estimate the number of persons with AIDS alive in San Francisco at various future times. That number-- the "AIDS caseload"-- is presently (March 1986) between 800 and 900. The model suggests that the caseload will rise steadily to approximately 1,600 by the end of 1987, and will remain near that level through 1990, whereupon it will begin slowly to decline. Thus, the city's programs for persons with AIDS-- Shanti, Hospice, etc.-- are advised to prepare for a caseload ultimately 80% to 100% larger than at present.

The caseload estimates depend on several assumptions, of which these are most critical: (1) that AIDS diagnosis rates among seropositives remain approximately as shown in Table 2; (2) that the mean survival time of persons with AIDS remains at about 18 months; (3) that in-migration and out-migration of persons with AIDS (or with a pre-AIDS condition) balance out one another; and (4) that AIDS remains, as at present, almost entirely a disease of gay and bisexual men. The last assumption seems a safe one, because the number of heterosexual IV drug users (the second most numerous at-risk population of San Francisco) who are infected with HTLV-III stood at only 800 to 1,000 as of March 1986; this pool of "potential future AIDS cases" was thus barely 3% of the similar pool of potential gay AIDS cases (see Table 1).

Turning now to the problem of relating HTLV-III exposure to actual infection by the virus, we must attempt estimates of parameters (5) and (6). The work of Bell and Weinberg, and others, indicates that gay male San Franciscans engaged in widespread "unsafe" sex practices with multiple partners, throughout the 1970's and early 1980's. Bell and Weinberg, for example, found that 55% of their 1971-era sample of gay men reported having had 20 or more sex partners in the prior year, and that 67% had engaged in receptive anal intercourse.

For purposes of simplifying the analysis, several assumptions are now made: (1) that receptive anal intercourse is the sole means of transmission of the HTLV-III virus to a gay man; (2) that participants in such intercourse choose their partners at random from the total population of gay male San Franciscans; (3) that all such partners who are HTLV-III seropositive are capable of transmitting the virus; and (4) that a steady, high incidence of anal intercourse prevailed among San Francisco gay men until the end of 1982, after which the AIDS epidemic motivated a drastic reduction of such practices.

Careful analysis of studies of gay sexual practices indicates that, on average, San Francisco gay men engaged in about 40 acts of receptive anal intercourse in each six-month period, during the 1970-1982 era. San Francisco data on the incidence of gonorrhea proctitis among men-- a gay man's affliction-- show a drop of fully 85% between the second half of 1982 and the second half of 1985. If these data truly reflect a drastic reduction in unprotected anal intercourse, it seems fair to assume that such intercourse had also fallen off by 85%-- that is, to an average of 6 acts per gay man in the second six months of 1985.

The proportion of gay men newly infected in a six-month period is, subject to the above-mentioned assumptions, available from this formula:

Proportion newly infected = (Number of unsafe sex acts) x
(Probability of act occurring between an infected and an uninfected male) x
(Probability of such an act causing infection of the uninfected male)

Let us abbreviate this formula to $P_n = N_u \times (P_i P_u) \times P_t$, where P_i is the proportion infected, and P_u the proportion not infected. The value of P_t is not known, but reasonable estimates of all the other factors are available from Table 1 and from the above analyses. Several values of P_t were plugged into the formula: .10, .05, .03, .02, .015, and .01. Of all of these, P_t = .015 most adequately accounted for the observed P_n, for two key six-month periods:

July-December 1982: $N_u = 40$

$P_i = .115$ } (from Table 1)
$P_u = .885$ }

$P_t = .015$

Predicted $P_n = 40 \times .115 \times .885 \times .015 = .061$

Observed $P_n = .06$

July-December 1985: $N_u = 6$

$P_i = .375$ } (from Table 1)
$P_u = .625$ }

$P_t = .015$

Predicted $P_n = 6 \times .375 \times .625 \times .015 = .021$

Observed $P_n = .02$

It is surprising to find that a "best fit" of the observed data is obtained by assuming that unprotected receptive anal intercourse with an infected partner carries a risk of only 1½% per act. This is only about one-tenth the risk involved with

sexual intercourse with a syphilis carrier. Nonetheless, this small P_t-value is practically the only way to account for the relatively slow spread of the HTLV-III virus during 1981-1983, when gay men in San Francisco were still engaging in so much "unsafe" sex with so many partners.

More careful analysis needs to be done on the statistics of exposure, particularly to probe the assumption that partners are selected at random (rather than from among a subset more likely to carry the virus) and the assumption that receptive anal intercourse is the only significant means whereby transmission occurs. If this analysis once again leads to the conclusion that P_t is small-- on the order of 1-3%-- several politically relevant consequences could emerge:

** "Case-tracing" of promiscuous gay men will be shown to be practically useless.

** Persons who are panicking because they made a few "slips" from an otherwise safe lifestyle can be reassured. Examples of such persons would be: "I cheated once on my lover three years ago, and now I find out that the man I was with has AIDS!", or "My lover is seropositive, and we've always played safe, but his condom broke once!"

** Repeated unsafe acts with a single ("monogamous") partner will be nearly as risky as single unsafe acts with many different partners.

** Awareness of the low value of P_t among the gay public may lead to a false sense of security and an undesirable resumption of unsafe sex practices.

These potential consequences should be kept in mind, as findings in this area are disseminated.

Finally, there is the question of the cumulative risk of various sexual patterns. It is obvious that "safe" sex leads to less cumulative risk than "unsafe" sex, even if the former is frequent and the latter infrequent. But for those men who choose to continue in "unsafe" practices, is monogamy a way of avoiding risk? Let us examine three patterns:

PATTERN A: Receptive anal intercourse 140 times with one partner.

PATTERN B: Receptive anal intercourse 70 times with each of two partners.

PATTERN C: Receptive anal intercourse twice each with 70 partners.

The cumulative risk is then given by

$$1 - (1 - P_t)^{N_u P_i}$$

where P_t is the probability that an unsafe act with an infected person results in HTLV-III infection, N_u is the total number of unsafe acts, and P_i is the probability that an unsafe act occurs with an infected partner. If we assume that all partners-- the seventy of the promiscuous fellow of Pattern C, as well as the one partner of the monogamous Pattern A man-- are chosen at random from San Francisco's gay population, then P_i will be equal to the seropositivity rate prevailing at the time. Looking at early 1982 and early 1986 as sample periods, Table 1 shows that the prevailing seropositivity rates were approximately 6½% and 40%, respectively. The cumulative risks are then:

San Francisco, early 1982 (6½% infection rate)		San Francisco, early 1986 (40% infection rate)	
Pattern A:	5.72% risk	Pattern A:	35.18% risk
Pattern B:	8.31% risk	Pattern B:	45.41% risk
Pattern C:	12.85% risk	Pattern C:	57.10% risk

Clearly, unsafe sex was riskier in early 1986 than four years previously, because the background infection rate was so much higher. Also, in 1982, monogamy offered a much greater reduction of risk than in 1986: Pattern A was nearly three-fifths safer than Pattern C in the earlier year, but only two-fifths safer in the later year. The inadequacy of monogamy is simply stated: if one selects a single partner who happens to be infected, then repetition of unsafe acts with that person will make it increasingly certain that the infection will be transmitted.

The counsel for gay San Franciscans which emerges from this analysis is quite straightforward: if you want to be promiscuous, confine your practices to "safe" ones. If you want to be monogamous, also confine your practices to the "safe" side, unless you are certain that both you and your partner are uninfected.

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Table 1

SEROCONVERSION ESTIMATES, GAY MALE SAN FRANCISCANS, 1978-1989

(Total gay male population = 70,000)

PERIOD	NUMBER SEROCONVERTING	CUMULATIVE SEROPOSITIVES	
1978	100		
Jan-June 1979	100		
July-Dec 1979	200	400	
Jan-June 1980	350		
July-Dec 1980	700	1,450	
Jan-June 1981	1,050		
July-Dec 1981	2,100	4,550	(6½%)
Jan-June 1982	3,500		
July-Dec 1982	4,200	11,550	
Jan-June 1983	3,500		
July-Dec 1983	3,150	18,950	(27%)
Jan-June 1984	2,800		
July-Dec 1984	2,450	24,150	
Jan-June 1985	2,100		
July-Dec 1985	1,750	28,050	(40%)
Jan-June 1986	1,400		
July-Dec 1986	1,400	30,850	
Jan-June 1987	1,050		
July-Dec 1987	1,050	32,950	(47%)
Jan-June 1988	700		
July-Dec 1988	700	34,350	
Jan-June 1989	700		
July-Dec 1989	700	35,750	(51%)

Table 2

ESTIMATED A.I.D.S. DIAGNOSIS RATES AMONG SEROPOSITIVES

MONTHS AFTER INFECTION	DIAGNOSIS INCIDENCE	CUMULATIVE
0 to 6	.0%	
6 to 12	.3%	
12 to 18	.6%	
18 to 24	1.0%	
24 to 30	1.6%	
30 to 36	1.6%	
36 to 42	1.5%	
42 to 48	1.4%	
48 to 54	1.3%	
54 to 60	1.2%	10.5%
60 to 66	1.1%	
66 to 72	1.1%	
72 to 78	1.1%	
78 to 84	1.0%	
84 to 90	1.0%	
90 to 96	1.0%	
96 to 102	1.0%	
102 to 108	.9%	
108 to 114	.9%	
114 to 120	.9%	20.5%

Table 3

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ESTIMATED A.I.D.S. DIAGNOSIS INCIDENCE AMONG GAY MALE SAN FRANCISCANS, BY HTLV INFECTION COHORT

INFECTION COHORT	SIZE OF COHORT	1979		1980		1981		1982		1983		1984		1985		1986		1987		1988		1989	
		1	2	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1			
1978	100	0	1	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Jan-June 1979	100	0	0	1	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1		
July-Dec 1979	200		0	1	2	2	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	
Jan-June 1980	350			0	1	2	4	6	6	5	5	5	4	4	4	4	4	4	3	3	3	3	3
July-Dec 1980	700				0	2	4	7	11	11	10	10	9	8	8	8	8	7	7	7	7	6	6
Jan-June 1981	1050					0	3	6	11	17	17	16	15	14	13	12	12	12	11	11	10	10	9
July-Dec 1981	2100						0	6	13	21	34	34	32	29	27	25	23	23	23	21	21	21	21
Jan-June 1982	3500							0	10	21	35	56	56	52	49	46	42	38	38	38	35	35	35
July-Dec 1982	4200								0	13	25	42	67	67	63	59	55	50	46	46	46	42	42
Jan-June 1983	3500									0	11	21	35	56	56	53	49	45	42	39	38	38	35
July-Dec 1983	3150										0	9	19	32	50	50	47	44	41	38	35	35	35
Jan-June 1984	2800											0	8	17	28	45	45	42	39	36	34	31	31
July-Dec 1984	2450												0	7	15	24	39	39	37	34	32	29	27
Jan-June 1985	2100													0	6	13	21	34	34	31	29	27	25
July-Dec 1985	1750														0	5	10	17	28	28	26	25	23
Jan-June 1986	1400															0	4	8	14	22	22	21	20
July-Dec 1986	1400																0	4	8	14	22	22	21
Jan-June 1987	1050																	0	3	6	10	17	17
July-Dec 1987	1050																		0	3	6	10	17
Jan-June 1988	700																			0	2	4	7
July-Dec 1988	700																				0	2	4
Jan-June 1989	700																					0	2
PREDICTED MORBIDITY		0	1	2	5	9	17	31	55	91	138	191	244	286	318	342	358	367	373	379	380	378	376
OBSERVED MORBIDITY*		0	0	2	4	7	14	28	54	95	122	187	255	328	336								

* Corrected for 11% "not San Francisco residents" and 2% "not gay males" among reported morbidity. Data prior to July 1981 are estimates.

Graph 1

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