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DOCUMENTED AIDS CASES AS THE BASIS FOR PROJECTIONS OF ADOLESCENCE HIV INFECTIONS IN THE U.S.

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ABSTRACT

Twenty percent of AIDS cases in the U.S. occur in individuals in the age range 20 to 29. The mean incubation time, the time from infection to the onset of AIDS, is in the order of 8 years. Therefore, most of these AIDS cases represent HIV infections that occurred during mid- to late-adolescence. About 800 officially reported cases in the age group 13 to 19 have occurred in the U.S. This low occurrence of AIDS should not be a source of complacency in assessing the need to provide education and behavioral alternatives to this age group. As the predominate mode of transmission of HIV infection shifts from gay-male behaviors and intravenous drug abuse (IVDA) to heterosexual intercourse, adolescents may be at significantly increased risk. The occurrence of STDs and early pregnancies indicate a significant rate of high-risk sexual behaviors in adolescents in the U.S. The rate of adolescent HIV infections can be projected by extrapolation from historical data and by epidemiological modeling and computer simulation. The rates of infection projected by these methods are sufficiently congruent to lend credibility to them. A rate of new HIV infections, in individuals in the age range of 13 to 19, in the order of 300,000 annually should be anticipated within the next 10 years.

INTRODUCTION

Most early estimates of the future incidence of AIDS were based on an unbounded geometrical increase in the number of diagnosed cases (Denning, 1988). Extrapolation from existing data is one means of projecting the future levels of AIDS cases. Historical trends in AIDS incidence are reported by the Centers for Disease Control (CDC) (Centers for Disease Control, 1992). The CDC considers delays in reporting and uses curve smoothing techniques (Karon *et al.*, 1989).

We note that since the population susceptible to HIV infection is finite, it is not possible to have an unlimited growth in numbers of infected individuals. Growth curve should be logistic or sigmoid in form. Such growth curves are familiar in population modeling (Burghes, 1980) and epidemiology (Lilienfeld & Lilienfeld, 1980).

Epidemiological models and their corresponding computer-based simulations also can be used to determine the effects of varying assumptions concerning the mechanisms for the spread/containment of the AIDS pandemic. We consider populations susceptible to AIDS, sub-populations of the general population, to be distinct classes within which the number of AIDS cases propagate. Transmission categories allowed definition of discrete susceptible populations for which independent growth curves can be calculated. Since cross-over between these populations occurs, it is necessary to provide for dynamic interactions between them in the calculation of total incidence rates.

The starting point for our projections of future rates of HIV infections in adolescents was the observation that twenty percent of U.S. AIDS cases occur in individuals in the age range 20 to 29. Since the mean incubation time to the onset of full-blown AIDS is in the order of 8 years, most of these AIDS cases represent HIV infections that occur during mid- to late-adolescence.

METHODS

CONSTRAINTS ON MODELING IMPOSED BY LIMITED DATA

The principal source of data concerning AIDS in the United States is the United States AIDS Program, Center for Infectious Diseases, CDC. This agency publishes a monthly "HIV/AIDS Surveillance Report," which comprehensively covers the cases of AIDS reported in the United States. These CDC reports are carefully annotated to show limitations on the accuracy and validity of the data. Other sources of information

include such agencies as the U.S. Department of Defense, which maintains detailed records for all military personnel and dependents, and the World Health Organization (WHO) which coordinates global HIV/AIDS data (Chin, *et al.*, 1990).

AIDS cases, reported by age at time of diagnosis, are shown in Figure 1. We focus here on the age groups 13-19 and 20-29. The age group 13-19 includes 789 AIDS cases (of a total of 206,392 reported by the CDC in January, 1992). This small number has been the basis for an argument that resources need not be dedicated to prevention programs targeted to this age group. When we examine the age group 20-29, however, the number of AIDS cases is clearly significant at 40,362. We will argue in this paper that these numbers indicate a high occurrence of new HIV infections in the age group of 13-19. We will project HIV infection rates for 13-19 year old individuals using both extrapolations from historical data and a transmission-based epidemiological model and computer simulation.

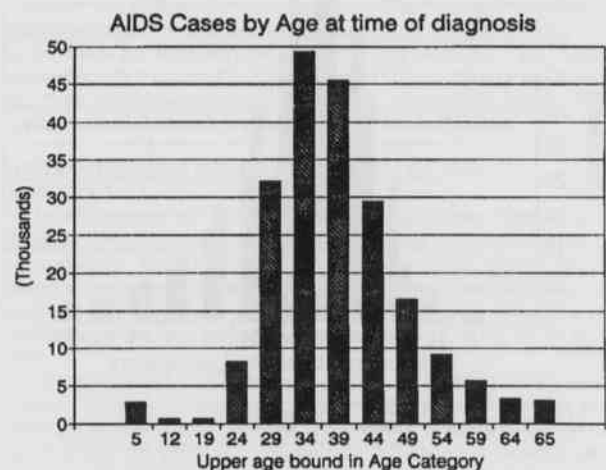


Figure 1. AIDS cases by age at time of diagnosis as reported by the Centers for Disease Control, January, 1992.

EXTRAPOLATION FROM HISTORICAL DATA

Using CDC data tabulated by age at time of diagnosis, we constructed a graph of the accumulated number of AIDS cases by age distribution (shown as the solid line in Figure 2). Using the working assumption of a mean interval between seroconversion and the onset of full blown AIDS of 8 years, we then constructed an average line for accumulated HIV infections also by age distribution (shown as the broken line in Figure 2).

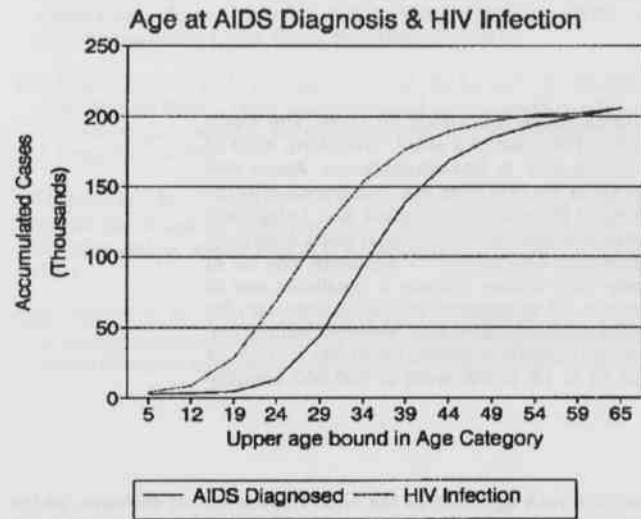


Figure 2: Accumulated Number of HIV Infections and AIDS Cases Displayed as a Function of Age at time of Infection or Diagnosis.

By linear interpolation we then computed the distribution of HIV positive cases according to the age groupings used by the CDC. This distribution is shown as solid bars in Figure 3. To assist in comparing the distributions, we included in Figure 3 the age distributed AIDS cases shown in Figure 1.

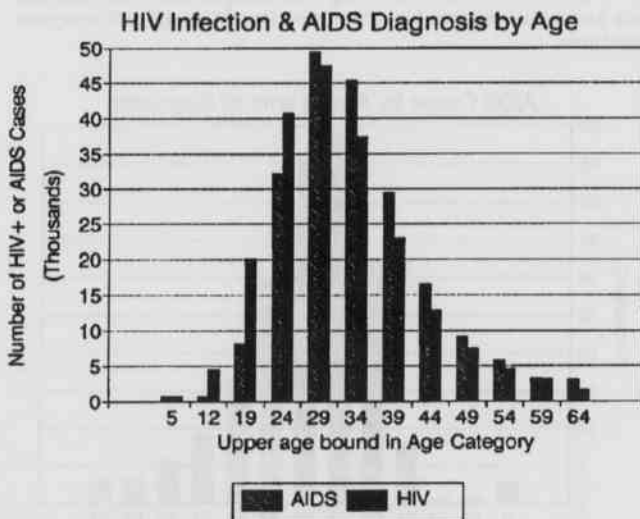


Figure 3. Distribution of HIV+ and AIDS Cases by Age Category at time of infection or diagnosis respectively.

An additional extrapolation is required. Since the CDC reports quarterly the number of AIDS cases diagnosed, we cautiously use these data for a near term extrapolation of future trends. This extrapolation is shown in Figure 4. In this admittedly simplistic approach, we assume three rates of growth: 5, 10, and 15% compounded. We use the lowest rate (5%) for comparison with results obtained by modeling and simulation that we describe in the following section.

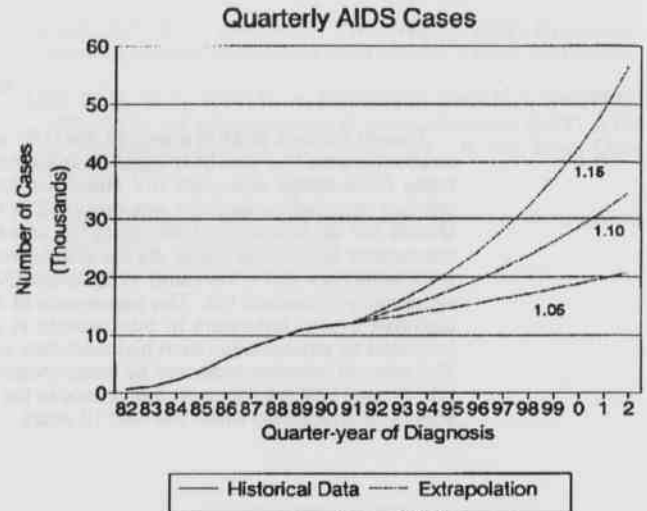


Figure 4. Historical and Extrapolated Quarterly AIDS cases in the U.S.

We agree with the CDC that the smoothed curve that they develop from these data "should be considered a description of the overall trend in AIDS cases but predictions of future numbers of cases should not be made by extrapolating the curve." The CDC further notes that "This curve emphasizes that the rate of increase in the incidence slowed during the middle of 1987." (CDC, 1992). On the basis of results obtained by modeling and simulation, we strongly suspect that this slowing is the result of reduced numbers of susceptible individuals in the most heavily impacted behavioral categories in the late 1980s, that is, homosexual males and intravenous drug abusers (IVDAs). We anticipate a resumption of the earlier trend in increasing rates as the epidemic moves to the larger heterosexual population.

Many other methods for projecting future trends in the AIDS epidemic have been reported (Brookmeyer & Damiano, 1989; Gail, 1990; Gruttola, *et al.*, 1989). To our knowledge, however, none have previously studied explicitly the problem of projecting HIV infection rates in adolescents.

EPIDEMIOLOGICAL MODELING AND COMPUTER SIMULATION

The basic transmission-based epidemiological model for HIV/AIDS used in this study consists of three main steps:

- (Step 1) Calculate the number of newly infected persons in each population class or category for the interval.
- (Step 2) Calculate the changes in sub-populations (net growth or decline).
- (Step 3) Update the population census and reiterate.

These steps are incorporated into the model (Goforth, 1989) that is depicted schematically in Figure 5.

We define the number of persons currently infected to be equal to the number infected in the previous interval plus the number of newly infected, minus the number of deaths. One significant working assumption for this study was a mean interval between seroconversion and the onset of AIDS of 8 years. Further, we assumed this to be the same for males and females for ages above 12 (Chin, 1990).

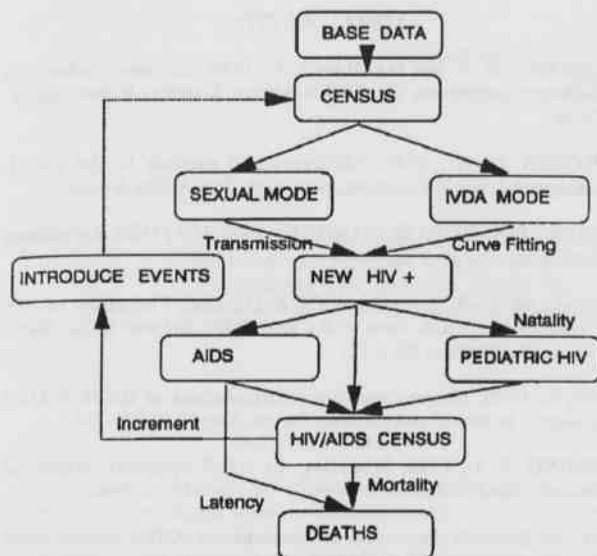


Figure 5. Schematic design of Epidemiological Model for AIDS.

Since the U.S. population of IV drug abusers is relatively small part of the total population and since such a high proportion of that population is already infected, we choose to use a curve-fitting approach to establish the contribution of that population to the AIDS census. Further, we calculate the number of pediatric HIV infections (defined here as patients under age 13) by using natality tables and age-distributed cohorts of HIV+ heterosexual females.

There is a considerable sensitivity of the cumulative number of AIDS deaths to uncertainties in behavioral and transmission factors. The probable impact of the introduction of vaccines of varying degrees of effectiveness in inoculation programs with differing start dates and durations also may be determined using the model shown in Figure 5 (Goforth, 1990). The ability of an epidemiological model to accommodate these calculations makes it a useful tool in establishing allocation of AIDS treatment/prevention resources.

RESULTS

CONGRUENCE OF PROJECTED RATES OF ADOLESCENT HIV INFECTIONS

The results of our projections, derived by both extrapolation from historical data and by modeling/simulation, are shown in Figure 6. We find that the rates of infection projected independently by these methods are sufficiently congruent to lend credibility to them. The trend to increased rates of infection will continue. A rate of new HIV infections, in individuals in the age range of 13 to 19, in the order of 300,000 annually should be anticipated within the next 10 years.

We estimate the range of uncertainty in these projections to be high, increasing from about $\pm 20\%$ in the 1993 projection to about $\pm 40\%$ in the 2001 projected rate. These estimates of uncertainty were derived by pushing the model/simulation with a range of input values for transmission risks, rates of partner change, and latency periods.

DISCUSSION

ADDITIONAL EXAMINATION OF THIS PROBLEM IS REQUIRED

Within the U.S. there are significant differences in the incidence of AIDS in different geographical areas, age groups, and socioeconomic

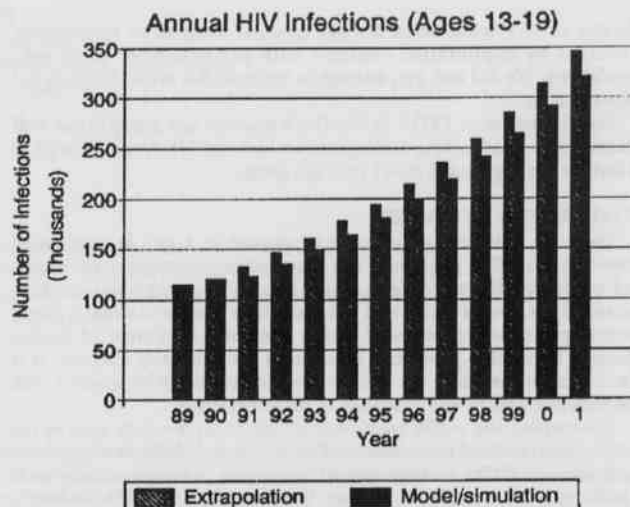


Figure 6. Projected annual HIV Infections for Ages 13-19 by Extrapolation and Modeling/simulation.

groups. The original model has been extended to accommodate these non-homogeneities and an algorithm has been devised for handling the migration of persons either between geographical areas or between age and socioeconomic groups. This algorithm appears to have utility and we have used it to explore the implications of population interactions and migrations on the spread of HIV/AIDS in the Southwest Pacific region (Goforth, 1990).

It is important to realize that many factors influencing the epidemiological model are not independent. Indeed, many interactions add significantly to the complexity of the resulting computer code. The code is modular, however, and each factor can be independently analyzed.

An example of a detailed calculation that could push the computation time beyond what is operationally acceptable for an interactive simulation system is the full inclusion of probabilistic data for the AIDS latency period. It is straight forward to use mean values for the latency period, e.g. 6.5 years for females and 7.8 years for males, but clearly the actual situation is complex and should be modeled in more detail if adequate data were available. Compounding this problem is how "entities" are defined for the simulation. The "entities" may represent individual members of small sub-populations or perhaps 1,000 or 10,000 individuals for members of large sub-populations. This contrasts markedly with the use of probabilistic data for the "risk of transmission" and "rate-of-partner-change" data where aggregated factors may be applied to the whole sub-population rather than individuals.

DISTINGUISHING CHARACTERISTICS OF THE AGE GROUP 13-19.

It is important to take note of some significant differences that distinguish the age group of 13-19 year olds for either younger or older age groupings. There are few HIV infected individuals entering the 13-19 year age grouping by cohort aging. Pediatric cases, particularly victims of perinatal infection, do not survive to become 13 year olds. This is the main reason for the relatively low occurrence of AIDS in 13-19 year olds.

There are about 3 million cases of STDs in 13-19 year olds reported annually in the U.S. This is one indicator of high-risk behaviors but, of equal significance, it is one that suggests that a pathway for infection exists in this age group that increases the likelihood of transmission per exposure. Other indicators of high-risk sexual behaviors are found in age differentiated birth rates and reports of sexual behaviors and attitudes. We note that self-reporting studies show that about one-half of public school students in grades 9 through 12 in Arkansas are sexually active.

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The risk of HIV infection in this age group is likely to be substantially increased by exploitative contacts with partners from older sub-populations. We did not, yet, attempt to estimate this effect on projected infection rates.

The occurrence of IVDA in the 13-19 year old age group is not well documented. As a working assumption we took the IVDA rate to be 25 % of that for the aggregated 20-45 year age group.

CONCLUDING REMARKS

There are a number of uses for simulation as a tool in forecasting related to the AIDS pandemic. The very nature of computer simulation and modeling demands clear definitions of the problems, working assumptions, input data, and relationships (mathematical). Good modeling requires objectivity and is generally intolerant of hidden agendas. Simulation provides a mechanism for sensitivity analyses. It is also a tool for handling the computations associated with systems with complex interactions and described in statistical terms.

Concerning the AIDS pandemic in the U.S., we note that as the predominate mode of transmission of HIV infection shifts from gay-male behaviors and IVDA to heterosexual intercourse, adolescents may be at significantly increased risk. Further, the occurrence of STDs and early pregnancies indicate a significant rate of high-risk sexual behaviors in adolescents in the U.S.

We have projected the rate of adolescent HIV infections by both extrapolation from historical data and by epidemiological modeling and computer simulation. We find that the rates of infection projected by these methods are sufficiently congruent to lend credibility to them. The annual rate of new HIV infections, in individuals in the age range of 13 to 19, in the order of 300,000 should be anticipated within the next 10 years. The low occurrence of AIDS in individuals 13 to 19 to date should not be a source of complacency in assessing the need to provide education and behavioral alternatives to this group.

The impact of under-reporting of AIDS was not considered. We note, however, that to the extent that under-reporting is significant, our projections are low.

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