Global surveillance and forecasting of AIDS*

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The short-term forecasting of future AIDS cases has been attempted by statistical extrapolations of the observed curve of reported AIDS cases. In areas where such reporting is very incomplete or has only recently started, extrapolation is not possible and an epidemiologically-based forecasting model has been developed to estimate the annual number of AIDS cases which may have occurred and to project the annual number and distribution of AIDS cases for up to ten years. This model, which relies on the current understanding of the epidemiology and natural history of HIV infections and on the available HIV serologic survey data, is used to provide estimates and short-term projections of AIDS cases for the USA, Europe, Africa and the world.

Because of the very long (mean of 8–9 years) incubation period between HIV infection and the development of AIDS, new cases over the next five years will be mostly derived from persons who became infected with HIV in or before 1987. WHO has estimated that 5–10 million persons worldwide were infected with HIV in 1987. Based on the lower estimate of 5 million, the cumulative number of AIDS cases which can be projected for the end of 1991 is over one million, and for the mid-to-late 1990s could reach 2 to 3 million.

HIV/AIDS will therefore be an increasing public health problem throughout the world. Health care systems everywhere will have to be strengthened to respond to this large toll of disease and death due to AIDS.

Introduction

At present (end of 1988), it is recognized that AIDS (acquired immunodeficiency syndrome) is a worldwide problem. However, after its identification in 1981, this pandemic was often characterized by denials and underestimation of its potential magnitude. It is now apparent that this unprecedented threat to global health is in its early stages, and its ultimate dimensions are difficult to estimate. From our current knowledge of AIDS, we consider that further spread is inevitable and the global situation will get much worse before it can be brought under effective control.

How many cases of AIDS can be expected to occur over the next five to ten years? Accurate estimates of these numbers are needed to effectively plan and direct both health care and public health programmes. However, accurate forecasting is not possible without a sound knowledge base about the past and present occurrence of AIDS. This article reviews the surveillance and global patterns of infections with the human immunodeficiency virus (HIV), the etiologic agent of AIDS, and provides some short-term forecasting of the HIV/AIDS situation in several major areas of the world.

Global surveillance

Worldwide AIDS surveillance is coordinated by a special unit in the Global Programme on AIDS (GPA) at the World Health Organization (WHO) in Geneva. Reports are received from Collaborating Centres, WHO Regional Offices, and ministries of health in countries. The accuracy and completeness of AIDS reporting vary markedly in different areas of the world. In most developed countries, it is believed that the majority of diagnosed cases are reported to national health authorities. In most

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of AIDS by several years, an optimal understanding of the current patterns of AIDS must be based upon an analysis of both HIV sero-prevalence data as well as reported AIDS cases. From such analyses we have distinguished three broad, yet distinct patterns of AIDS. The explanation for the existence of these patterns includes the apparent date of HIV entry and/or period when HIV began to spread extensively in the population and details of sexual behaviour and intravenous (IV) drug use in the population. The three general patterns of AIDS are:

**Pattern I:** in these areas, HIV probably began to spread extensively in the late 1970s. Most cases occur among homosexual or bisexual males and intravenous drug users in cities. Heterosexual transmission is responsible for only a small percentage of cases but is increasing. Overall population seroprevalence is estimated to be less than 1% but has been measured to be over 50% in some groups of persons practising high-risk behaviours such as men with multiple male sex partners and IV drug users. This pattern is typical of industrialized countries with large numbers of reported AIDS cases, including North America, many western European countries, Australia, New Zealand, and many urban areas in Latin America.

**Pattern II:** in these areas, most cases occur among heterosexuals and HIV probably began to spread extensively in the 1970s. The male to female ratio is approximately 1:1, and as a result mother-to-infant transmission is common. IV drug use and homosexual transmission are not believed to be major factors. In a number of countries, overall population seroprevalence is estimated at more than 1% and in some urban areas up to 25% of the sexually active age group is infected. Transmission through contaminated blood continues in those countries that have not yet implemented nationwide donor screening. This pattern is at present observed in sub-Saharan Africa, and increasingly in some countries of Latin America, especially in the Caribbean.

**Pattern III:** in these areas, HIV was probably introduced in the early to mid-1980s and only small numbers of AIDS cases have been reported. Homosexual and heterosexual transmissions have only recently been documented. Cases have generally occurred in persons who have travelled to pattern I or II areas, or who have had sexual contact with individuals from such areas. Cases due to use of imported blood products have been reported, and in a few countries, these cases comprise the largest percentage of reported AIDS cases to date. This pattern is found in areas in eastern Europe, North Africa, the Middle East, Asia, and most of the Pacific (excluding Australia and New Zealand).
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Comments on AIDS projections

It is difficult to predict the long range (>10 years) dimensions of this pandemic for the following reasons.

(a) It has only been possible to follow the scope of this pandemic for about seven years.

(b) HIV infection in humans is believed to be life-long and there is no similar retrovirus infection in humans, which has been adequately studied, to provide an analogy for predictions.

(c) Our knowledge of the behaviours associated with transmission of this virus (vaginal or anal intercourse and intravenous drug use), as well as the number of persons engaging in such behaviours, is incomplete and their investigation is difficult.

(d) The proportion of HIV-infected persons who will ultimately develop AIDS is not known. Current estimates are that about half will develop AIDS within 10 years. Whether this proportion will reach 75% or close to 100% within 15 to 20 years after infection can only be answered with time.

(e) Most of the data collected to date on the clinical aspects of HIV infections have been for HIV-1. The relative pathogenicity and distribution of HIV-2, which was identified in the mid-1980s from West Africa, need to be determined. At the present time, it is believed that HIV-2 may be less pathogenic than HIV-1, but conclusive evidence is still lacking.

(f) The relative roles of other factors in facilitating HIV transmission and/or progression to clinical disease after infection need to be determined. At the present time, it has been postulated that other sexually transmitted diseases (STD), especially those which are associated with genital ulcers, may be important co-factors for the transmission of HIV. Similar or different co-factors may influence the pattern and/or rate of progression from HIV infection to the development of AIDS.

(g) The degree and pattern of infectiousness of HIV-infected persons have not yet been worked out. There is some evidence to suggest that infectiousness increases markedly during the later clinical stages of HIV infection.

In spite of these difficulties and uncertainties, short-term predictions (over the next 5–10 years) of the impact of AIDS can be reasonably derived from current knowledge of the natural history of HIV infections and from the limited surveillance data (especially HIV serosurvey data).

Short-term forecasting

The short-term forecasting of future AIDS cases has been attempted by statistical extrapolations (or “fitting”) of the observed curve of reported AIDS cases. Such forecasting assumes that after adjustment for inherent reporting delays, the past trends of reported cases will continue, at least over the short-term, in a similar pattern. These forecasting models are believed to be reasonably accurate for several years and all such models have projected several-fold increases of AIDS cases over the next five to ten years (1, 2).

In countries where reporting of AIDS cases is grossly incomplete, or where reporting has been started over the past couple of years, it is not possible to extrapolate future AIDS cases from the pattern or number of previously reported cases. In such situations, an epidemiologically based forecasting model has been developed to estimate the current cumulative number of AIDS cases in a specified population and to project the number and general distribution of AIDS cases which may be expected within a ten-year period. The following estimates and assumptions, based on available HIV serologic survey data and on the current understanding of the epidemiology and natural history of HIV infections, are needed to operate this model (Table 2).

(1) The year when HIV infection probably began to spread extensively in the population: for most pattern I or II countries extensive spread probably did not begin until the late 1970s or early 1980s.

(2) The cumulative prevalence of HIV infections in the population: such an estimate can be derived from HIV serologic survey data when available.

(3) The number of persons infected with HIV in each year (annual infected cohorts), starting from the year when HIV began to spread extensively: the available epidemiological cohort data suggest that the incidence of HIV infections was highest in the early 1980s and the rate of increase, at least in some areas, may have slowed in recent years. The cumulative prevalence curve of HIV infections is, thus, assumed to be more asymptotic in shape than exponential and HIV infections in this forecasting model are distributed to each annual infected cohort in such a pattern.

(4) The annual rate of progression from HIV infection to the development of AIDS: this rate has

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<thead>
<tr>
<th>Table 2: Estimates and assumptions for projection of AIDS cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Estimate when HIV began to spread widely</td>
</tr>
<tr>
<td>2. Estimate HIV seroprevalence</td>
</tr>
<tr>
<td>3. Distribute annual HIV-infected cohorts</td>
</tr>
<tr>
<td>4. Apply annual rate of progression to AIDS</td>
</tr>
<tr>
<td>5. Project future incidence of HIV infections</td>
</tr>
</tbody>
</table>

been estimated from cohort studies of HIV-infected persons to be about 20% within five years and close to 50% within ten years. In addition, for this model, the progression rate is projected to be 75% in 15 years and about 95% within 20 years. However, this progression rate is not applicable to mother-to-infant transmission of HIV infections. For paediatric AIDS, the following assumptions and estimates were used: (a) one quarter (25%) of infants born from HIV-infected mothers may be infected; (b) the development of AIDS in a cohort of HIV-infected infants is 25% during the first year of life, 20% in the second year, 15% in the third, and 10% each in the fourth and fifth years, with a cumulative rate of 80% by the fifth birthday.

(5) The incidence of HIV infection in each future year: in this model, a gradually decreasing annual incidence of HIV is estimated till the year 2000. Short-term projections are virtually independent of the future trends and of new HIV infections which will occur in the end of 1988 and later. The vast majority of AIDS cases and deaths which can be projected within the next five years would still be expected to occur even if all HIV transmission were to cease in 1988. The mean incubation period from infection to the development of AIDS has been estimated by AIDS modellers to be about eight to nine years. Thus, the majority of new AIDS cases which will become manifest over the next four to five years will be essentially derived from the pool of persons who became infected with HIV in or before 1987.

Using these estimates and assumptions, both the annual incidence and cumulative prevalence of both paediatric and adult AIDS cases in a given population can be estimated by applying the specific (adult or paediatric) annual progression rate for the development of AIDS to each of the annual HIV-infected cohorts. All of the assumptions and estimations used in this model will need to be modified when and if additional data become available to warrant any change.

HIV/AIDS projections

Over the next ten years, the major impact of AIDS in pattern I countries (basically all of the Western industrialized countries, including Australia and New Zealand) will continue to be among homosexual/bisexual men and IV drug users since they comprise the vast majority of the pool of currently HIV-infected persons. The US Public Health Service estimated in June 1988 that about 400,000 cases of AIDS will occur primarily among males in the 20-49-year age group in the USA by the early 1990s. This estimate is almost identical to that which can be calculated using the adult AIDS forecasting model which we have developed. The assumptions we used to forecast AIDS in the USA were that HIV began to spread extensively starting about 1980 and that about one million Americans were infected with HIV as of 1987. Our annual projected cases for the United States using our forecasting model "fits" rather well with the reported AIDS case data (Fig. 2).

In Europe, an estimate of close to 500,000 HIV-infected persons, as of the end of 1987, was made by national AIDS programme representatives at a WHO meeting on HIV/AIDS surveillance in early 1988. Assuming that HIV did not begin to spread extensively in Europe until about 1982, our adult AIDS forecasting model projects that there will be a cumulative total of over 20,000 AIDS cases by the end of 1988 and that by the early 1990s over a hundred thousand cumulative cases can be expected. Our projected cases for Europe also gives a good fit to the reported AIDS case data from Europe (Fig. 2).

Uninfected homosexual men have continued to acquire HIV infections, but at a lower incidence rate in the past couple of years. This decreasing incidence of new infections is consistent with reported changes in sexual behaviour and with decline in other sexually transmitted diseases in homosexual men (3). Nevertheless, considering the magnitude of the populations at risk at present and in the future, many hundreds of thousands of additional homosexual men, IV drug users and others may become infected during the next five years. Current information in pattern I areas is insufficient to predict the future incidence of HIV infection resulting from heterosexual transmission, but increases over the present low numbers of such HIV infections are likely over the next few years.

In pattern II countries the major focus of HIV infections is at present among heterosexuals with multiple sexual partners, primarily in the major urban areas. HIV seroprevalence rates of 50% or more are often found among female prostitutes in many cities of central Africa and from 10% to 25% among the sexually active age group in these same cities (4). Whether the current incidence of acquisi-


Fig. 2. Reported and projected AIDS cases in USA, Europe, Africa and the world, 1980–92 (the gaps between the tops of some columns and the curve designate unreported cases).

The proportion of new HIV infections is decreasing or not is the subject of intensive study. According to the AIDS forecasting model we have developed, the number of AIDS cases which can be expected to occur over the next ten years, in the most severely affected pattern II countries, will not come close to reversing the positive population growth rate which has been projected for most central African countries. This finding is similar to that of Anderson et al. (5) who used a different modelling method which included estimates and assumptions regarding HIV transmission. Nevertheless, during this period, there will in urban areas be a marked and very selective decrease in the projected population increase among the very young (due to mother-to-infant transmission of HIV) and among sexually active persons with multiple sex partners (Fig. 3). The overall positive population growth rate of 3–4% a year for many central African countries may be reduced to about 2–3%. However, for a “typical” central African country with a total population of about 20 million in 1987, the numbers of AIDS-related deaths which can be expected by the mid-to-late 1990s, among adults in their most productive years, are expected to be about a quarter of a million. This selective impact on young and middle-aged adults, including business and government workers, as well as members of the social, economic and political elites, will have grave social/economic consequences well beyond the absolute number of deaths.

Beyond this short-term forecast, if HIV infections continue to increase in urban areas and spread...
extensively in rural areas, then the potential for a negative population growth rate will be present. Thus, the long-term demographic impact of AIDS in pattern II countries cannot be projected with any degree of certainty until it can be determined whether such spread of HIV will occur or not.

How extensively HIV will spread in pattern III countries can be estimated from patterns of other sexually transmitted diseases. Also, where IV drug use is prevalent, HIV/AIDS will be a major potential problem. Such a potential problem has as of late 1988 been documented to be a very real one in Bangkok, Thailand, where the prevalence of HIV infection among the estimated 60,000 IV drug users in that city has dramatically increased from <1% in August 1987 to about 30% as of July 1988 (U. Thongchai, unpublished data). Using our AIDS projection model on those IV drug users who, we estimate, have been or will be infected during 1988 and 1989 gives a projection of up to 5000 AIDS cases from this cohort alone by 1993–94 and over 10,000 by 1997.

In 1987, WHO estimated that between five and ten million persons worldwide were infected by HIV. Based on the lower estimate of about 5 million HIV-infected persons as of 1987, the number of AIDS cases which we project by 1991 is over one million; beyond five years, the toll of AIDS cases from those millions of persons already infected as of 1987 can be expected to double or triple. A comparison of our projected annual number of AIDS cases globally with the reported AIDS data received by WHO emphasizes that a large proportion of AIDS cases are not reported and that the majority of the non-recognized or non-reported cases are in Africa (Fig. 2).

As previously mentioned, this projected toll can be expected regardless of the numbers of new HIV infections which will be occurring in 1988 and later. In addition, this projection is primarily for adult AIDS cases. Preliminary modelling results for mother-to-infant transmission of HIV indicate that several hundred thousands of HIV-infected infants, most of whom will die as a result of their HIV infection before the age of five years, can be expected before the end of this decade.

Conclusions

It is thus very clear that HIV/AIDS will be an increasing public health problem throughout the world in the next decades. Accurate forecasting of the number of AIDS cases will depend primarily on two main factors: the number of HIV-infected persons and what proportion of them will ultimately develop AIDS. The distribution of AIDS cases, by year of occurrence, will be largely determined by the time period when HIV began to spread extensively and by the shape or density of the annual cumulative prevalence of HIV infections in the specified population.

By the early 1990s, the cumulative total of global AIDS cases can be expected to be over one million, and by the late 1990s to be about two to three million. Health care systems throughout the world will need to be strengthened to respond to this toll of disease and death.

The greatest public health challenge facing all AIDS control programmes is to reduce, to the maximum extent possible, the transmission of HIV. As with most other human infectious disease agents, an endemic level of infections and disease due to HIV will eventually be established. How high or low that endemic level will be, will depend on the effectiveness of the HIV/AIDS prevention programmes that are now being developed.

Résumé

SIDA: Surveillance mondiale et prévisions

Des estimations précises et des prévisions du nombre et de la distribution des cas de SIDA sont nécessaires pour planifier et diriger efficacement les programmes de soins de santé et de santé publique. Cependant, la science—ou l’art—de la prévision en matière de SIDA n’en est encore qu’à ses débuts. Les prévisions à court terme des cas de SIDA ont été faites par extrapolation statistique (ou “ajustement”) de la courbe observée des cas déclarés de SIDA. Dans les régions où ces déclarations sont incomplètes ou là où l’on commence seulement à déclarer les cas, il n’est pas possible de procéder à cet exercice. Dans de telles régions, un modèle de prédiction basé sur l’épidémiologie a été conçu pour estimer le nombre annuel de cas de SIDA et pour projeter ce nombre ainsi que la distribution des cas pour les 10 prochaines années. Ce modèle de projection repose sur la connaissance actuelle de l’épidémiologie et de l’histoire naturelle des infections à VIH, et sur les données des enquêtes séroépidémiologiques. Il est utilisé pour fournir des estimations et des projections à court terme des cas de SIDA aux États-Unis, en Europe, en Afrique et dans le monde.

La grande majorité des cas de SIDA projetés pour les 5 années à venir se déclareraient de toute façon même si la transmission du VIH cessait après 1988. Du fait de la longue période d’incubation—8 à 9 ans en moyenne—séparant
l'infection par le VIH de l'apparition du SIDA avéré, les nouveaux cas de SIDA qui se produiront dans les 5 années à venir toucheront principalement des personnes déjà infectées par le VIH avant 1988. En 1987, l'OMS estimait à 5–10 millions le nombre de personnes infectées par le VIH dans le monde. Si l'on prend l'estimation la plus faible, soit environ 5 millions de personnes infectées en 1987, le nombre cumulatif de cas de SIDA qui peut être projeté pour 1991 est supérieur à 1 million. Entre 1995 et l'an 2000, il pourrait atteindre 2 à 3 millions.

Au cours des 10 prochaines années, dans la plupart des pays industrialisés le SIDA continuera à frapper essentiellement les hommes homosexuels et bisexuels et les toxicomanes par voie intraveineuse, qui représentent actuellement la grande majorité des sujets infectés par le VIH dans ces pays.

Le nombre prévisible de cas de SIDA dans le pays d'Afrique centrale le plus touché par l'épidémie entraînera un déclin prononcé et sélectif de la croissance calculée de la population urbaine, mais n'aura qu'un effet minime dans la plupart des régions rurales. Cependant, l'effet sélectif du SIDA sur les jeunes adultes et les adultes d'âge moyen vivant en milieu urbain, y compris les hommes d'affaires et les fonctionnaires tout comme les membres de l'élite sociale, politique et économique, aura de graves conséquences sociales et économiques, bien au-delà du nombre absolu de décès provoqués par le SIDA dans la plupart des pays d'Afrique centrale.

Il est évident que l'épidémie de VIH/SIDA deviendra au cours des deux prochaines décennies un problème de santé publique de plus en plus aigu. Dans le monde entier, les systèmes de soins de santé devront être renforcés pour faire face au fardeau inévitable que représente le SIDA et son lourd tribut de maladies et de décès.

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References
