GAO

United States General Accounting Office

Report to Congressional Requesters

June 1989

AIDS FORECASTING

Undercount of Cases and Lack of Key Data Weaken Existing Estimates

GAO/PEMD-89-13

GAO

United States
General Accounting Office
Washington, D.C. 20548

Program Evaluation and
Methodology Division

B-230539

June 1, 1989

The Honorable John D. Dingell
Chairman, Subcommittee on Oversight and
Investigations
Committee on Energy and Commerce
House of Representatives

The Honorable Henry A. Waxman
Chairman, Subcommittee on Health and
the Environment
Committee on Energy and Commerce

The Honorable Ron Wyden
Chairman, Subcommittee on Regulation
and Business Opportunities
Committee on Small Business

This report responds to your September 30, 1987, request for an assessment of national forecasts of the AIDS epidemic. We have reviewed the models and data underlying existing national forecasts of the cumulative number of AIDS cases, indicating the direction of major biases where possible. Our review has also identified the most realistic range possible of the cumulative number of AIDS cases by the end of 1991.

As agreed with your staff, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after its issue date. At that time, we will send copies to the Secretary of Health and Human Services, the Director of the Centers for Disease Control and other interested parties, and make copies available to others upon request.

This report was prepared under the direction of Lois-ellin Datta, Director of Program Evaluation in Human Services Areas. Other major contributors are listed in appendix III.

Eleanor Chelimsky
Assistant Comptroller General

Executive Summary

Purpose

The acquired immune deficiency syndrome (AIDS), a fatal disease caused by the human immunodeficiency virus (HIV), has become a critically important international health concern. Many aspects of health-care policy, including directions in preventive education as well as private-sector initiatives, hinge on assessments of the future course of this epidemic, and forecasters have attempted to predict the likely toll of the HIV virus in coming years. But, considering the limits of what is presently known about this new disease—and recognizing the uncertainty that is always involved in making predictions—how confident can policymakers be even in short-range AIDS forecasts?

In September 1987, the chairmen of three House subcommittees—the Subcommittee on Oversight and Investigations, the Subcommittee on Health and the Environment, and the Subcommittee on Regulation and Business Opportunities—requested an assessment of national forecasts of the AIDS epidemic. Expressing concern about the widely varying national forecasts that have been made, the chairmen asked that GAO (1) undertake a methodological review of the forecasting models and examine the variation in existing forecasts, (2) assess the data underlying components of those models, and (3) identify—in light of current uncertainties—the most realistic range possible for the likely size of the future epidemic.

Background

Less than a decade ago, AIDS was virtually unknown in this country; as of year end 1988, over 80,000 cases had been reported via the national surveillance system. According to the Centers for Disease Control (CDC), this total is expected to more than triple by year end 1991. The scope of this report is limited to (U.S.) national forecasts of cumulative AIDS cases through 1991 that were produced by September 1988.

Results in Brief

GAO identified 13 national forecasts of the cumulative number of AIDS cases through the end of 1991. GAO found that these forecasts understate the extent of the epidemic, primarily because of biases in the underlying data. Definitional problems and the lack of key studies contributed to an underrepresentation of the epidemic in the national AIDS surveillance data and in most forecasts. Taking account of whether the existing forecasts had been adjusted to compensate for data biases, GAO estimates that a realistic range of forecasts would be 300,000 to 480,000 cumulative cases. This compares with a range of most likely (called "best") estimates from the 13 models of 120,000 to 400,000 cases through the end of 1991.

GAO found some problems with the comprehensiveness, empirical basis, or assumptions of each forecasting model. The absence of data on key components of the epidemic (for example, the size of risk groups) has led all 13 forecasts to rely on the national AIDS surveillance data. These data represent cases that have been diagnosed and reported by the medical community to CDC. Although not developed for use in forecasting, these data were used for this purpose both by CDC and other forecasters. GAO systematically assessed the quality of the national AIDS surveillance data and found 13 different problems that could lead to biased forecasts. Using the best available information on these problems—local studies and data tabulations by CDC and others—GAO made necessary adjustments to forecasts. In many cases, the forecasts had not been previously adjusted or had been underadjusted for problems.

GAO estimates that the net effect of these problems may be that only about two thirds of all cases of AIDS and other fatal HIV-related illnesses were captured in the data underlying existing national forecasts. This would imply that to capture all such illnesses, AIDS surveillance data should be adjusted upwards by an estimated 50 percent. CDC's most recent forecast adjusted the data by only 19 percent, taking into account fewer problems than were recognized by GAO.

GAO's Analysis

Forecasting Methods and Estimates

National AIDS forecasts are based on four types of models or forecasting methods. Extrapolation models extend trends in national surveillance data into the future; the "best" estimates generated by each of these models range from 200,000 to 325,000 cases through year end 1991. "Back calculation" models estimate past trends in HIV infection by combining data on the incubation period (time-to-AIDS) with the national surveillance data; they then predict future AIDS cases among already-infected persons. The best estimates from back-calculation models range from about 120,000 to 295,000 cases. Macro-level models supplement surveillance data and incubation-period estimates with assumptions about the future course of the epidemic; they simulate HIV transmission and the development of AIDS at the "macro" or societal level. These models' best estimates range from about 160,000 to 400,000 cases. Micro-level models simulate individual-level behaviors and events that contribute to the spread of the disease; existing forecasts of this type converge at about 250,000 cumulative AIDS cases through year end 1991.

The Quality of Data Used by National Forecasters

Surveillance systems for notifiable diseases serve to alert officials to public-health threats yet usually underrepresent the true size of the problem, in part because they depend on the medical community to report diagnosed cases to local health authorities. To capture the maximum number of AIDS cases, CDC supports active AIDS surveillance programs in state and local health departments and in September 1987 expanded its definition of AIDS. But since recent forecasts have relied primarily upon cases diagnosed before July 1987, the change in the definition has not yet improved the accuracy of forecasts.

Of the 13 data problems identified in GAO's review, 6 had the effect of underforecasting the true number of cases of AIDS and other fatal HIV-related illnesses. (For example, GAO estimates that CDC's limited list of qualifying AIDS illnesses excluded 15 percent of all fatal HIV illnesses from the surveillance data used by forecasters; although 6 percent were later captured by the definition change, an estimated 9 percent are still not covered by the new definition.) Two additional data problems resulted in delayed counts of AIDS cases, while two more resulted in small overcounts, and three represent data discontinuities. CDC and local surveillance officials have been aware that such problems, if uncorrected, would lead to biased forecasts. Although some local studies have been done, GAO found that rigorous national studies had not been conducted and that the net effect of these problems on national forecasts had not been estimated. This may be linked to limited resources in CDC's Surveillance Branch for HIV disease. (See pages 55-56.)

Because undercount problems differentially affect subgroups, forecasts for some subgroups—for example, drug users and inner-city minorities—may be especially affected. With respect to "risk groups," reported cases of women with AIDS—many of whom had been exposed through heterosexual risks—are likely to lack information on risk exposures. Items concerning heterosexual risks were often skipped by medical or local health staff on case-report forms, but no sign of these omissions was included in CDC's data documentation. In addition, although specific heterosexual risks (such as having a drug-using sex partner) have not been included in the surveillance data made available by CDC for public use, unpublished CDC analyses show an increasing number of cases stemming from heterosexual contact with drug-using partners. Some forecasts have assumed no expansion of the epidemic in the heterosexual population. However, GAO believes that the true proportion of heterosexual cases may be somewhat higher than the often quoted 4 percent, that the ability to track trends in certain heterosexual risk groups has been limited, and that the accuracy of some forecasts has been affected.

The time between HIV infection and the development of AIDS is long and variable. Some forecasts assumed median incubation periods that are unrealistically low, resulting in projections that also may be low.

Overall Assessment of Forecasting Models

GAO assessed the models on four criteria: (1) comprehensiveness, (2) soundness of the empirical base, (3) reasonableness of assumptions, and (4) adequacy of the corrections for data biases. The most comprehensive models (micro-level simulations) proved to be the least empirically based, due to the lack of needed empirical data on, for example, risk behaviors and HIV transmission. By contrast, the least comprehensive models (extrapolations) were based only on trends in surveillance data. Also, some models were based on questionable assumptions, and most adjusted for few of the data problems identified in this report.

Recommendations to the Secretary of Health and Human Services (HHS)

GAO recommends that the Secretary of HHS require the Director of the Centers for Disease Control to (1) conduct rigorous national studies of the net effect of biases in the national AIDS surveillance data in order to improve national estimates of the current and projected size of the epidemic; (2) assess whether CDC's Surveillance Branch for tracking cases of AIDS and HIV-related diseases has sufficient resources to plan, fund, monitor, review, and disseminate such studies; and (3) incorporate additional information on risk group membership into the CDC public use data. GAO also recommends that the Secretary of HHS review existing and ongoing empirical studies of risk groups and risk behaviors as well as of HIV transmission and the current level of HIV infection—all of which are key components in the micro-level simulation forecasts—to determine where additional data are most needed.

Agency Comments

At the request of the Subcommittees, formal agency comments were not sought. Informal comments were obtained from CDC and from other forecasters whose work is reviewed here. Where appropriate, their responses have been incorporated into the text. CDC noted that they are planning to conduct assessments of the national AIDS surveillance data and have requested additional funding in their 1990 budget proposal for this purpose.

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Abbreviations

AIDS	Acquired immune deficiency syndrome
CDC	Centers for Disease Control
FTE	Full-time equivalent
GAO	U.S. General Accounting Office
HCFA	Health Care Financing Administration
HHS	U.S. Department of Health and Human Services
HIV	Human immunodeficiency virus
IV	Intravenous
NIR	No identified risk

Introduction

Background

Acquired immune deficiency syndrome (AIDS) has become a critically important international health concern. Caused by the human immunodeficiency virus (HIV), AIDS is a fatal disease that severely compromises the human body's ability to fight infections. The virus is transmitted through sexual contact, through sharing needles in intravenous drug use, and from mother to newborn infant.[1] According to the Centers for Disease Control (CDC) of the U.S. Public Health Service, the majority of cases identified to date have been concentrated in certain geographic areas and among members of "risk groups" such as homosexual men and intravenous drug users.

Since AIDS was first clinically identified in 1981, growth in the number of reported cases has been dramatic, prompting considerable concern about the future course of this epidemic. As reported by CDC, over 80,000 cases had been identified in the United States by year end 1988, and more than 45,000 people had died of AIDS.

One fundamental question surrounding the epidemic concerns the number of cases that are likely to occur in coming years. To answer this question, numerous forecasts have been made by federal agencies (most notably, CDC) and by researchers at universities and research organizations, as well as in the insurance industry. At the national level, such projections have important implications for decisions about federal resource allocation and public financing of health care services.

Because the forecasts for AIDS cases occurring through 1991 have varied widely—with the best estimates going from about 120,000 to 400,000 and with more extreme lower and upper-bound forecasts having been reported[2] —questions have arisen concerning the merits and accuracy of these figures. Given the disparities among competing forecasts, it is important that the underlying basis for the numbers be made clear and that, to the extent possible, a more realistic range be identified.

Three House subcommittee chairmen—the chairman of the Subcommittee on Oversight and Investigations of the House Committee on Energy and Commerce, the chairman of the Subcommittee on Health and the Environment of the House Committee on Energy and Commerce, and the

[1] Blood transfusions and blood products had represented another avenue of transmission. However, beginning in 1985, the successful screening of blood and blood products has virtually eliminated this mode of transmission in the United States. Accidental infection through needle-stick accidents or handling infected blood or other bodily fluids is rare, but has occurred.

[2] This wider range goes from a lowest projected lower bound of less than 100,000 to a highest projected upper bound of 750,000 cumulative cases by the end of 1991.

chairman of the Subcommittee on Regulation and Business Opportunities of the House Committee on Small Business—have asked that we assess the methods used to produce current forecasts of AIDS cases. Specifically, we were asked to (1) identify existing national forecasts of AIDS cases, (2) undertake a methodological review of the models used to produce these forecasts, (3) assess the data underlying these models, and (4) identify—in light of current uncertainties about the future course of the epidemic—the most realistic range of estimates.

Objectives, Scope, and Methodology

Objectives

Based on the request, our objectives were (1) to identify existing national forecasts and to assess the extent of variation or uncertainty in these predictions, (2) to review the forecasting models used in making these predictions, (3) to assess the quality of the main types of data used in the models, and (4) to evaluate the major types of AIDS forecasting models overall and determine a realistic range of estimates for the cumulative number of AIDS cases through year end 1991.

Scope

Because of time constraints, the scope of this report is limited to those U.S. national forecasts of AIDS cases for 1991 that were produced by September 1, 1988. Excluded from coverage here are (1) those forecasts of certain components of the epidemic that do not include a projection of AIDS cases (that is, forecasts of HIV infections, AIDS costs, and AIDS deaths that do not project numbers of cases); (2) forecasts of AIDS cases for states or local U.S. areas, for other nations, or for a single "risk group" (for example, homosexual men) that do not include a U.S. national projection; (3) U.S. national forecasts of AIDS cases that do not include the year 1991; and (4) AIDS forecasting models that are not yet operational (that is, that have not yet produced an actual projected number of cases).

Methodology

Identifying National Forecasts

In order to comprehensively cover forecasts meeting the stated criteria (national forecasts of AIDS cases for 1991), we searched bibliographic data bases, performed hand-checks of recent issues of selected journals, and surveyed experts in the AIDS research field. Over 60 experts were sent copies of our preliminary bibliography and were asked for comments and updates. As a result of these efforts, we identified 13 national forecasts that had been conducted between 1986 and 1988. These forecasts had been made by federal agencies (for example, CDC and the Health Care Financing Administration), by analysts within research institutions and universities, and by members of the insurance industry. The selective bibliography at the end of our report identifies the models we reviewed and also includes key sources selected from our complete bibliography.

Reviewing Models

In order to describe and evaluate the models fairly according to the general guidelines provided by earlier GAO reports,[3] we have reviewed the published literature, requested related materials from authors, and contacted authors to check interpretations or to obtain needed information (for example, on methods used) that was not provided in published materials or in the main information source. For each type of model or forecasting approach, we have described the general characteristics, the principal assumptions, the empirical basis for the forecasts that have been reported, and variations in applications developed by different forecasters.

Assessing Data Quality

The quality of the major types of data used in the forecasts was systematically reviewed by our staff and outside consultants. Original sources cited by AIDS forecasters were identified and reviewed in terms of the methodological procedures that were employed. This review included assessments of sample size, presence or absence of biases in sample selection, adequacy of measurement protocols, appropriateness of analytic treatments of the data, and adequacy with which results were

[3]These include USDA's Commodity Program: The Accuracy of Budget Forecasts (GAO/PEMD-88-8); DOD Simulations: Improved Assessment Procedures Would Increase Credibility of Results (GAO/PEMD-88-3); and Retirement Forecasting (GAO/PEMD-87-6A and GAO/PEMD-87-6B).

reported. Additional reports of similar types of data and published critiques of such data were also examined. We synthesized these assessments to generate a list of factors that could bias forecasts and determined, where possible, the likely direction and magnitude of the effects of these biases on AIDS projections. This approach was followed separately for each major type of data.

Overall Adequacy of Forecasting Models

The likely accuracy of a forecast depends on both the model that is used and the quality of data supporting the model. It is possible to have a model that is comprehensive—in the sense that it considers all relevant parameters for estimating the future course of the AIDS epidemic—but relies on poor data, makes unreasonable assumptions, or fails to take into account known inadequacies in the data. Our overall judgment of adequacy takes into account not only the comprehensiveness of each type of model, but also the quality of the underlying data and the reasonableness of assumptions.

Based on our overall assessment of forecasting models and data quality, we identified a more realistic range of estimates. First, in order to take full account of uncertainties about the future course of the epidemic, we considered separately the "best estimate" forecast and the lower and upper-bound forecasts produced by each model. Second, forecasts based on dubious assumptions were judged unrealistic. Third, forecasts that were based on biased data and that had not "corrected for" these data biases were adjusted appropriately. These adjusted forecasts then were used to define the more realistic range.

At the request of the Subcommittees, formal agency comments were not obtained. Informal comments were obtained from CDC and from other forecasters whose work we reviewed.

Our review was conducted in accordance with generally accepted government auditing standards.

Organization of This Report

Chapter 2 presents our summary of the 13 existing national forecasts of the cumulative number of AIDS cases projected for 1991. Chapter 3 describes these models, their assumptions, and procedural variations across forecasts. Chapter 4 evaluates the quality of the major data sources (that is, the national AIDS surveillance data and time-to-AIDS data) that underlie these models. Chapter 5 combines judgments of the models and of the accuracy of data, yielding our estimate of a more realistic range of cumulative AIDS cases through 1991. Chapter 6 presents our conclusions and recommendations.

Existing National Forecasts and Variation in Predictions

What lies in store for the nation with respect to AIDS? How grim are the present prospects—and how much difference might behavior changes or medical advances make in the short and long run? These are the sorts of basic questions for which policy makers need answers if they are to allocate resources properly for health services, consider alternative health care options and health financing programs, or evaluate prospective education and behavior-modification programs. And these are the sorts of questions that forecasters can address. But, considering the limited knowledge about this new disease and the uncertainties always involved in making predictions, how confident can policymakers be in even the short-range predictions that forecasters have made to date?

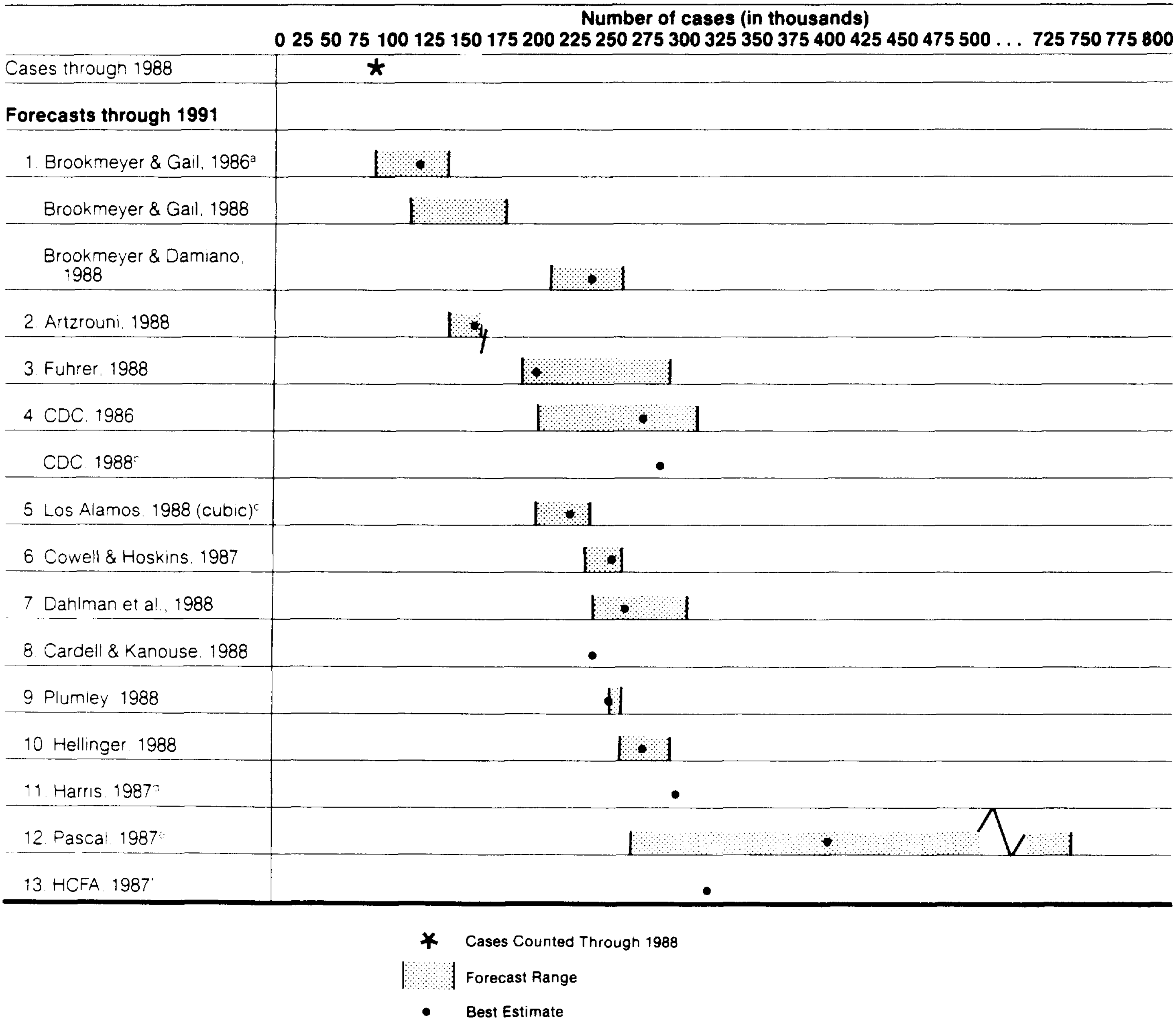
We identified 13 existing national forecasts for 1991. The earliest of these was published in 1986, and the most recent were conducted in 1988; we included only forecasts provided to us by September 1988.[1] In the aggregate, they show that a wide range of values has been predicted for the number of individuals who will develop AIDS by the end of 1991, with best estimates extending from about 120,000 to 400,000 cases. Further, most forecasters have allowed for a margin of error by providing a range of possible predictions; the lower bounds of these ranges differ considerably from upper bounds—sometimes by about 100,000 cases or more. Uncertainty about the future of the AIDS epidemic, even in the near term, derives from multiple sources of error. But for most of these forecasts, the range given is based on a single—often different—source or type of error. Of course, the variation in these forecasts for 1991 (made between 1986 and 1988) would be even greater if longer-term forecasts had been attempted.

Existing Forecasts: "Best Estimates" and Ranges for 1991

Thirteen forecasts of the cumulative number of AIDS cases in the United States by 1991 have been made. (See figure 2.1.) These forecasts—perhaps appropriately—indicate a high level of uncertainty concerning the relatively short-term future course of the epidemic.

[1] An additional forecast, provided to us after our "cut off" date, was included in an October 1988 publication and had been presented orally earlier. (See Hay, Osmond, and Jacobson, "Projecting the Medical Costs of AIDS and ARC in the United States," Journal of Acquired Immune Deficiency Syndrome, October 1988. Hay et al. forecast 166,000 new cases between January 1988 and December 1991; taken together with 63,000 cases diagnosed prior to 1988, the cumulative total would be about 230,000 cases through the end of 1991.)

Figure 2.1: National Forecasts of Cumulative AIDS Cases Through 1991, From Lowest Lower Bound to Highest



[a]Brookmeyer, in a personal communication to GAO, indicated that the range around the Brookmeyer and Gail (1986) forecast consists of high and low figures derived as part of an analysis designed to show the sensitivity of forecasts to the time-to-AIDS estimates used; he stated that these upper and lower bounds were not intended as plausible forecasts.

[b]CDC's 1988 forecast was primarily intended to predict cases through year end 1992 and did not include a range for cases forecast for 1991; however, CDC did provide a range to us: 185,000 cases to 320,000 cases.

[c]The Los Alamos cubic forecast is based on their cubic-growth prediction formula: the complex micro-simulation model developed at Los Alamos has not yet been used to produce an actual forecast of numbers of cases and therefore is not included in the scope of this report.

[d]Harris's best estimate shown above (295,000) is for cases through the end of 1991 and was provided to us to supplement his published forecasts, which were for cases through the first quarter of 1991.

[e]The range of cases in the Pascal forecast, according to a representative of the Rand Corporation, was merely an intermediate step in predicting hospital costs; it was not intended as a plausible forecast of the number of cases.

[f]The HCFA forecast is based on a combination of two figures, both of which were obtained from CDC: the 1986 CDC forecast for 1991 and a 1986 CDC statement that the case data represent a 20 percent undercount. HCFA increased the CDC forecast by 20 percent.

In most instances, the AIDS forecasters have provided a range of predicted AIDS cases for 1991 as well as a "best estimate" or mid-level prediction. Although the majority of the "best-estimate" forecasts indicate some degree of agreement or convergence across forecasts (hovering around 250,000 cumulative AIDS cases), the set of predicted ranges shown in figure 2.1 indicates that there is considerable uncertainty. Notably, five forecasters specify ranges of 50,000 or more cases for 1991, with three of these—Fuhrer, Pascal, and CDC—providing ranges with lower and upper bounds that differ by about 100,000 or more predicted cases. In addition to the uncertainty underlying each forecast range, there is variation across the ranges and best estimates provided by different forecasters.

Multiple Sources of Uncertainty Underlie Forecast Ranges

Each forecast range derives from a recognition of underlying uncertainty or error. Some of the forecast ranges are based on statistical principles (for example, projection error). Other ranges are based on the individual forecaster's uncertainty about choice of a forecasting model, key parameter values, or assumptions regarding the course of the epidemic. Generally, a single range is based on only one type of error. No one range encompasses all major sources of uncertainty.

Statistical error is the source of uncertainty for CDC forecasters. The CDC ranges are based on the likely "margin of error" involved in estimating a projected trend line for AIDS cases.[2]

Structural or substantive issues underlie other forecasters' ranges, as follows:

- Uncertainty associated with the choice of a forecasting method or a prediction equation is the basis for the ranges provided by three forecasters (Pascal, Fuhrer, and Hellinger).
- Uncertainty about the correct value for a key parameter—the time elapsing between a person's infection with HIV and his or her development of clinical AIDS—is the basis for other ranges of possible forecasts (Brookmeyer and Gail, 1986, 1988; Artzrouni).
- Uncertainty about key assumption(s) concerning the future spread of HIV infection underlies the ranges in three forecasts (Plumley, Cowell and Hoskins, and Dahlman et al.).

Some elements of substantive error[3] as well as statistical error underlie the range shown for Brookmeyer and Damiano; but, as these forecasters themselves emphasize, the range does not encompass all sources of uncertainty.

Uncertainty Across Forecasts

Most of the individual ranges shown in figure 2.1 represent only one of several possible sources of uncertainty. A conservative approach to ascertaining the full measure of uncertainty for 1991 forecasts might therefore be to combine all ranges. Following this approach, the lowest lower-bound for 1991 is only 84,000 cases, whereas the highest upper-bound is 750,000 cases.

The magnitude of this combined all-forecasts range is sobering; the upper bound is nine times the size of the lower bound, and the variety of possibilities for the epidemic that are thus encompassed prohibit use of the range as a meaningful guide to health services planning.

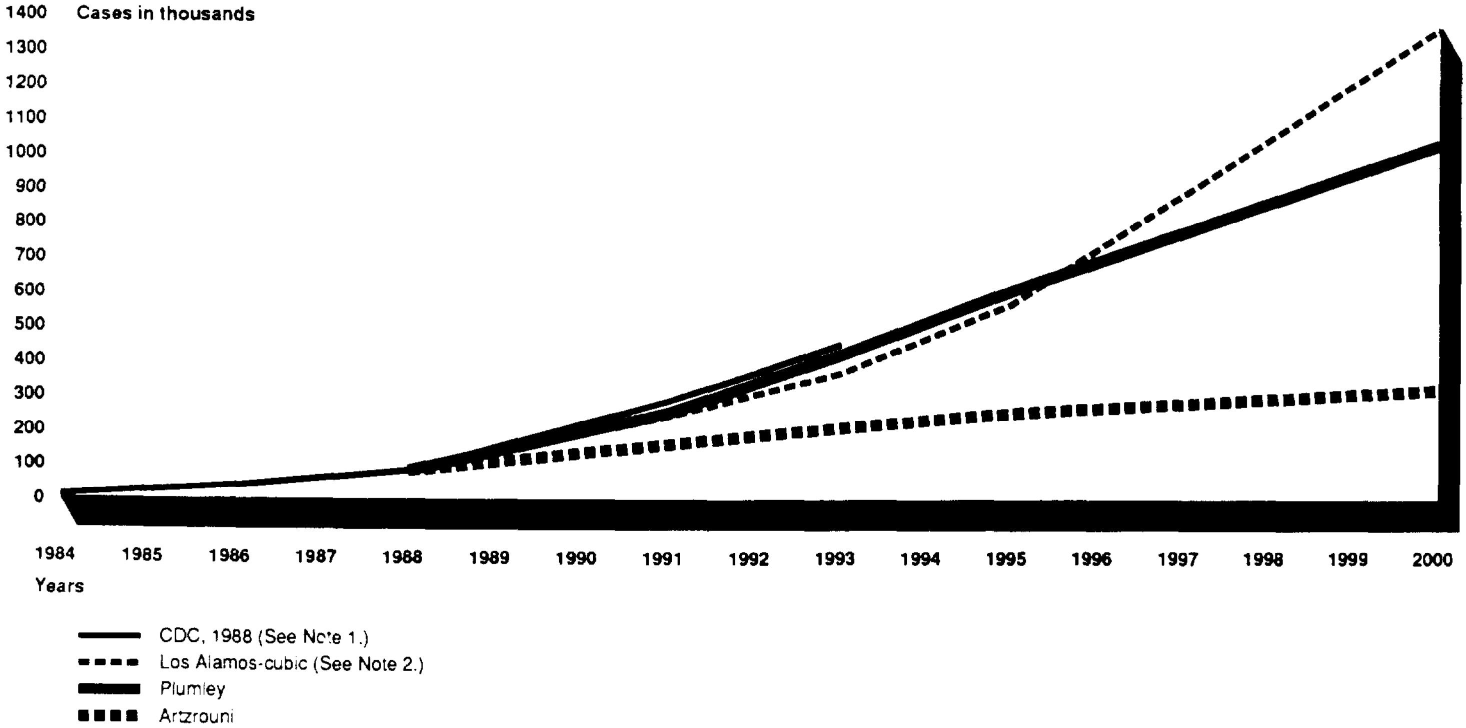
[2]This includes the errors that are associated with CDC data adjustment procedures, that is, corrections for estimated time lags in the reporting of diagnosed AIDS cases to CDC.

[3]These include alternate use of step-function and logistic curve in the back-calculation procedures and alternative assumptions as to whether there will be no new infections or new infections will continue at an extrapolated rate.

Of course, the 84,000 to 750,000 range for 1991 includes the lower and upper bounds of forecasts that were published in 1986 and 1987 and that were in some cases conducted as early as 1985.[4] Forecasts dated 1988 cover a range from about 120,000 to 320,000—a difference of only 200,000 cases; but these are essentially 3 1/2-year forecasts. By the same token, longer range projections (for beyond 1991) can be expected to reveal greater differences among forecasts. When the course of the predicted epidemic is examined, it is apparent that even the "best-estimate" forecasts diverge much farther from one another as they are projected farther into the future. (See figure 2.2.)

[4]In fact, the authors of the published forecasts with the lowest lower bound (84,000) and highest upper bound (750,000) indicated in their reviews of our report that these figures were not intended as plausible forecasts. Brookmeyer indicated that the lower-bound 84,000 figure had been derived as part of a sensitivity analysis that was conducted more as a "mathematical exercise" than as an effort to reach a plausible lower-bound forecast. A representative of the Rand Corporation, which published Pascal's report forecasting AIDS costs, indicated that the forecast of AIDS cases was merely an intermediate step towards forecasting AIDS costs and was not intended as a plausible forecast of the epidemic. These forecasts are nevertheless included in this report—with appropriate caveats in the tables that include them—because they illustrate the level of uncertainty surrounding the epidemic as recently as a few years ago and because the numbers are included in publicly available documents.

Figure 2.2: Selected Longer-Term Forecasts of the Course of the AIDS Epidemic



Note 1: From 1984 through 1988, the CDC trend line indicates reported cases; from 1988 through 1993, it indicates CDC's forecast.

Note 2: We performed the extrapolation to the year 2000 for the Los-Alamos-cubic equation by using the Los Alamos prediction formula.

Methodological Review of Forecasting Models

As previously noted, existing forecasts of future AIDS cases are based on four major types of models or forecasting methods: (1) extrapolation models that extend recent trends in AIDS cases into the future; (2) "back calculation" models that estimate the number of persons who are already infected with HIV and then predict how many of them will convert to clinical AIDS by specific future dates; (3) macro-level simulation models that chart the future spread of HIV and resultant AIDS, based on assumptions about the general course of the epidemic; and (4) micro-level simulation models, which specify the individual-level behaviors and events contributing to HIV transmission and development of AIDS—and which have numerous uses in studying the epidemic besides forecasting.[1]

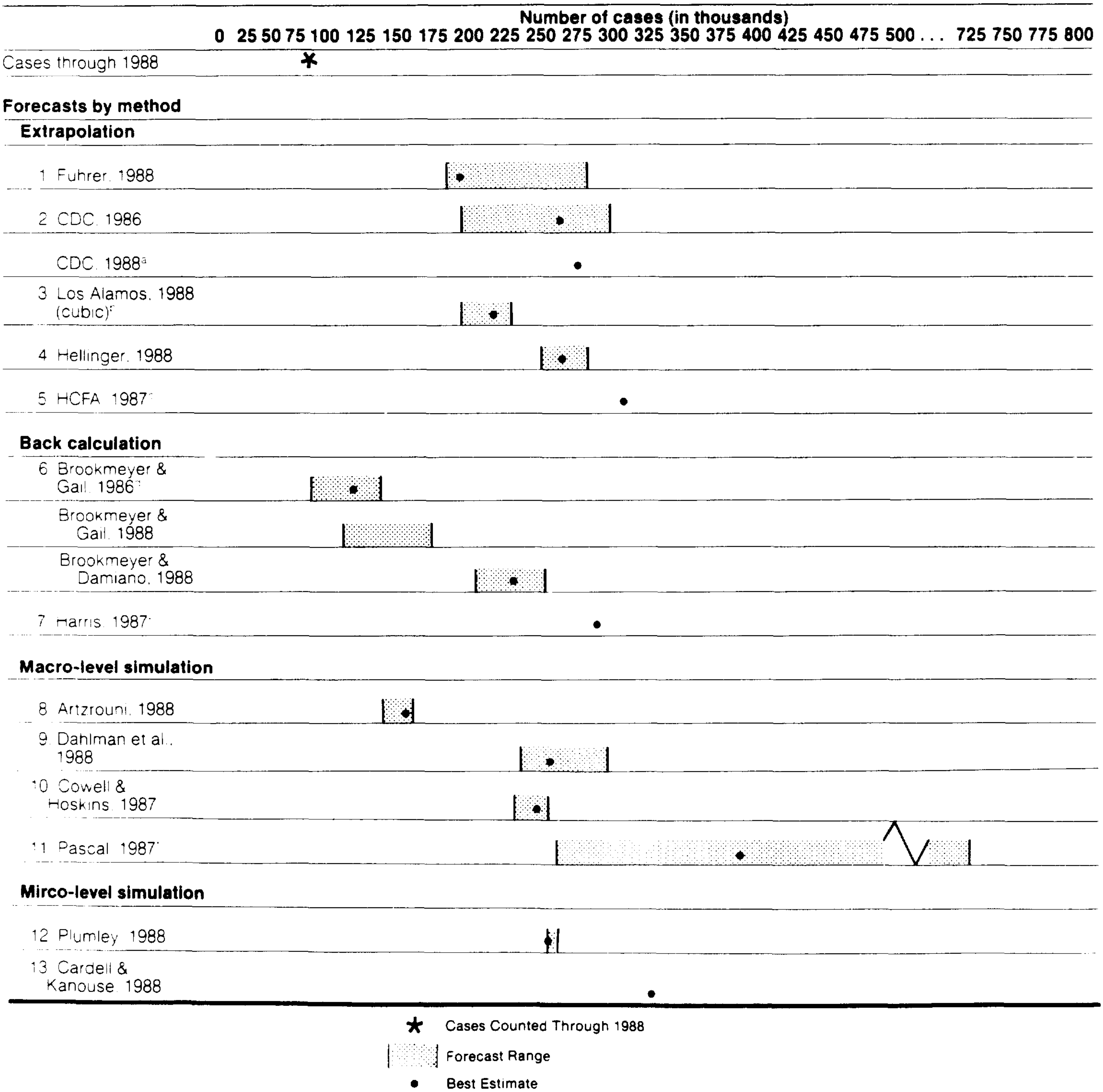
Differences between the four major forecasting methods account for some of the diversity in AIDS-case projections discussed in chapter 2. Forecasts for 1991 based on extrapolation models vary from a lower bound of under 200,000 cumulative AIDS cases to the HCFA forecast of about 325,000. Back-calculation forecasts are generally lower—running from a lower bound under 100,000 to an upper bound that is just under 300,000. Macro-level simulations are the most variable, with the bounds running from about 140,000 to 750,000. The two "micro" models have both forecast about 250,000 AIDS cases. (See figure 3.1.)

A good deal of the diversity in forecasts is, however, due to differences within the major forecasting methods, as follows:

- For each forecasting method, differences in "best estimate" forecasts stem from differences in the individual models that were developed by the various forecasters using that method. For example, differences across the five extrapolation models are associated with differences in their "best-estimate" forecasts.
- For each forecast, the range or difference between the specified lower and upper bounds reflects recognition of statistical error or of uncertainty concerning alternative specifications that might be chosen for the model—or both.

[1] May and Anderson (1987) state that such models "help to clarify some of the essential relations between epidemiological factors, such as distributed incubation periods and heterogeneity in sexual activity...They also help to identify what kinds of epidemiological data are needed to make predictions of future trends" (p. 137).

Figure 3.1: National Forecasts of Cumulative AIDS Cases Through 1991, by Forecasting Method



[a]CDC's 1988 forecast was primarily intended to predict cases through year end 1992 and did not include a range for cases forecast for 1991; however, CDC did provide a 1991 range to us: 185,000 cases to 320,000 cases.

[b]The Los Alamos cubic forecast is based on their cubic-growth prediction formula; the complex micro-simulation model developed at Los Alamos has not yet been used to produce an actual forecast of numbers of cases and therefore is not included in the scope of this report.

[c]The HCFA forecast is based on a combination of two figures, both of which were obtained from CDC: the 1986 CDC forecast for 1991 and a 1986 CDC statement that the case data represents a 20 percent undercount. HCFA increased the CDC forecast by 20 percent.

[d]Brookmeyer, in a personal communication to us, indicated that the range around the Brookmeyer and Gail (1986) forecast consists of high and low figures derived as part of an analysis designed to show the sensitivity of forecasts to the time-to-AIDS estimates used; he stated that these upper and lower bounds were not intended as plausible forecasts.

[e]Harris's best estimate shown above (295,000) is for cases through the end of 1991 and was provided to us to supplement his published forecasts, which were for cases through the first quarter of 1991.

[f]The range of cases in the Pascal forecast, according to a representative of the Rand Corporation, was merely an intermediate step in predicting hospital costs; it was not intended as a plausible forecast of the number of cases.

As summarized in table 3.1, AIDS forecasting models are based on four major methods and differ in terms of (1) the general logic characterizing each of the four methods, (2) the main data sources and types of assumptions underlying each of the four methods, (3) variation in the numbers of cumulative AIDS cases forecast for 1991 (that is, lowest lower bound to highest upper bound for each forecasting method), (4) the individual models that were developed by different forecasters who used a particular method, and (5) the alternative bases of the lower and upper bounds provided by the various forecasters using each method.

Table 3.1: Summary of Major Forecasting Methods and Differences in Models

Forecasting method	Five descriptors: 1. Logic of method	2. Data and assumptions	3. Variation in forecasts[a]	4. Differences across models	5. Bases of forecast ranges
Extrapolation (5 models)	Equation describing trend is extended into future.	Surveillance data; assumes current trend continues	185,000 to 324,000	Different types of equations	Statistical error; different types of equations
Back-calculation (2 models)	Earlier HIV-infection trends are calculated; then the number who convert to AIDS is predicted.	Surveillance data, time-to-AIDS studies; assumes no new HIV infections	84,000 to 295,000	Different estimates of the time-to-AIDS; use/non-use of supplemental method for new HIV infections	Same as 4; plus statistical error
Macro-level simulation (4 models)	Past and future HIV infection trends are modelled; expected future AIDS cases are predicted.	Surveillance data, time-to-AIDS studies; makes assumptions about HIV infection spread	143,000 to 750,000	Assumptions differ concerning HIV infection spread.	Same as 4
Micro-level simulation (2 models)	Risk groups, individual risk behaviors, HIV transmission, and the development of AIDS are simulated in computer models	Surveillance data, time-to-AIDS studies, sketchy data on behavior, HIV transmission; assumptions about behavior and transmission	240,000 to 256,000	Models differ regarding whether infectivity is varied and whether mixing is limited by age, race, location.	Change versus no change in frequency of risk behaviors (Plumley)

[a]Lowest lower bound to highest upper bound.

Extrapolation

1. General Description and Logic of the Extrapolation Method

The extrapolation method uses the pattern of recent trends in AIDS cases and, with a variety of statistical models, projects the future course of the epidemic.

Specifically, extrapolation forecasters determine a trend line that summarizes or describes the form of the relationship between calendar time (1982, 1983, 1984, 1985, and so forth) and the numbers of new or additional AIDS cases that were actually diagnosed during each (earlier) time interval. This line or curve is defined in a two-step process. First, the forecaster chooses a type of equation that is deemed appropriate for describing the observed trend; the choice may be based on trying out different types of equations (for example, linear, quadratic, cubic, log-logistic) that describe various kinds of trend lines or curves. Second, the forecaster fits or "tailors" the selected equation to the existing trend data; that is, the specific coefficients for the equation are determined by means of minimization-of-error procedures (typically, a least-squares process). Once the coefficients have been determined, the curve or trend line can be extended into the future, and a forecast is then easily made for any specific point in time.

2. Data and Assumptions

The five extrapolation models that have produced national forecasts of AIDS cases by the end of 1991 are all based on a single data source: the national AIDS surveillance data that are maintained by the Centers for Disease Control (CDC) of the Public Health Service of HHS. All five extrapolation forecasts represent an extension of trends observed for total AIDS cases throughout the United States; these forecasts are not based on separate consideration of—and hence do not draw upon surveillance data for—local trends either within demographic subgroups or within AIDS risk groups.[2]

Generally, the extrapolation forecasting method assumes that the existing pattern of national trends (that is, existing trends in new AIDS cases from the early 1980's to the present) will continue unchanged into the future years for which predictions are made.

3. Variation in Forecasts

As shown in figure 3.1, the "best-estimate" extrapolation forecasts for 1991 go from a low of 200,000 cumulative AIDS cases (Fuhrer) to a high of 325,000 (HCFA); this represents a difference in expectation of 125,000 AIDS cases. The individual prediction ranges are also broad.

4. Differences Across Models and "Best Estimates"

The five extrapolation models differ principally in terms of the types of equations chosen by the forecasters to best depict existing trends.[3] The equations, which differ with respect to the numbers of mathematical terms that are included and the powers to which they are raised, depict curves of various steepness or shape (for example, steep upward curve, "S"-shaped curve).

There are other differences as well. The equations have been fit to national surveillance data from different years; for example, CDC's 1988

[2]Trends in cases for various population subgroups could be separately tracked, extrapolated, and forecasted, with the various forecasts then being combined for a total population figure. This practice was not followed by the AIDS forecasters identified for this report. CDC has, however, projected the percentages of cases to be composed of various subpopulations and applied these percentages to the overall forecast to obtain subgroup forecasts.

[3]See appendix II for specific prediction equations.

forecast for 1991 used data on cases diagnosed through June 1987, whereas CDC's earlier (1986) forecast used data through May 1986. In addition, differing adjustments have been introduced to compensate for data deficiencies (for example, lags in the reporting of diagnosed cases to CDC or failure to report some cases). HCFA and CDC's 1988 forecasts, as well as Hellinger's, correct for both of these problems.[4] Other extrapolation forecasters have corrected for lags in reporting diagnosed cases but not for cases that have never been reported.

In four out of five cases, the best-estimate forecast is based on extrapolating a chosen trend-line or equation.[5] Specifically, both CDC forecasts (1986, 1988) are based on a quadratic formula and Box-Cox transformation for period incidence.[6] The Los Alamos forecast is based on a cubic formula for cumulative cases and a corresponding quadratic formula for period incidence.[7] Fuhrer's "best estimate" is based on a logistic formula. HCFA's forecast adjusts the 1986 CDC forecast to compensate for CDC's estimated effects of undercounting of cases due to physician failure to diagnose cases definitively and for the underreporting to CDC of cases diagnosed by physicians. In the fifth instance (Hellinger), the best estimate is a midpoint between forecasts produced by two alternative trend lines (based on different equations).

5. Bases for Forecast Ranges

Extrapolation forecasts have allowed for margins of error based on statistical uncertainty or, alternatively, on uncertainty in the choice of the appropriate prediction equation.

The rather wide range CDC constructed for its 1986 forecast—about 200,000 to 310,000 cumulative AIDS cases by 1991—is based on their estimate of statistical uncertainty surrounding their best-estimate forecast. CDC forecasters recognized (1) the uncertainty or error associated

[4]Hellinger used a somewhat different approach in that his prediction equation was based on the date each case was reported rather than the date each was diagnosed.

[5]Generally, forecasters have chosen equations based on what appears to provide a "good fit"—although goodness of fit tests and comparisons are not specified by the forecasters. In one instance (Fuhrer), the basis for the choice of the equation is stated as being experience in the form (logistic curve) that epidemics have followed.

[6]See Box and Cox, 1964.

[7]The Los Alamos cubic formula was derived using the same procedures as CDC used to derive their formula; that is, rather than selecting a cubic formula a priori or on an intuitive basis, the Los Alamos group conducted preliminary analyses using a Box-Cox transformation and nonlinear regression; these analyses yielded results almost identical to a cubic formula.

with fitting a specific trend line to existing data and (2) the likely error in the adjustments made to "correct for" lags in reporting.

Fuhrer and Hellinger each used different types of trend-line equations to determine their lower and upper bounds. Essentially, this approach to constructing a forecast range reflects uncertainty about the most appropriate type of equation to describe the trend line. Specifically, Fuhrer's lower bound is based on a quadratic exponential equation, whereas his upper bound is based on a linear equation with a Box-Cox transformation. Hellinger obtained his lower and upper bounds by using two alternative quadratic formulas--one with and one without a square-root transformation.

The Los Alamos forecasters specify an 8-percentage point "margin of error" as the basis for characterizing their range of estimates.[8]

Back Calculation

1. General Description and Logic of the Method

The "back calculation" method of forecasting future AIDS cases is based on the fact that trends in new AIDS cases reflect existing or past trends in the spread of HIV infection. Levels of HIV infection in earlier years have determined the current AIDS caseload. The two trends (HIV infections and new AIDS cases) are separated by a time factor—that is, the incubation period—which is the time that elapses between the point when a new HIV infection occurs and the point when that infection converts to a condition diagnosable as AIDS. Existing HIV trends thus represent a key to short-term forecasting of new AIDS cases.

No generalizable national data exist on HIV infection trends since the early 1980's,[9] but forecasters can "calculate backwards" to estimate these HIV trends. Specifically, combining estimates of the time-to-AIDS with information on recent trends in new AIDS cases, one can project

[8]This margin of error (plus or minus 8 percent) for the Los Alamos 1991 forecast was indicated to us in a personal communication (January 1989).

[9]Trends in HIV infections have been tracked among civilian applicants for military service since October 1985. (See M. R. Peterson, Morbidity and Mortality Weekly Report, 37:44 (November 11, 1988), pp. 677-679, for an update.) Other populations being tested include blood donors, Job Corps entrants, hospital patients, and newborn infants. (See Centers for Disease Control, Morbidity and Mortality Weekly Report, 36:S-6 (December 18, 1987), pp.4-6.) Questions have arisen, however, about the representativeness of some of these populations or about their constancy over time, or both.

back to earlier years and the sizes of cohorts of persons then infected with HIV (hence, the term "back-calculation"). To use a hypothetical example, suppose that at the very start of the epidemic in the United States, 100 cases were diagnosed in one year—and that it was known that only 5 percent (or 1/20) of all HIV-infected persons convert to AIDS within a year of infection; calculating backward in time, one would estimate that 20 times 100 persons (or 2,000) had become infected during the prior year.

Once HIV-infection trends from the start of the epidemic up to the present have been "calculated," forecasters again turn to estimates of the time-to-AIDS. These estimates of the time-to-AIDS are now applied to the HIV infection levels in order to calculate forward—thus predicting the numbers of (already infected) persons who will develop AIDS by a specific future date.

To continue the hypothetical example introduced in the preceding paragraph, suppose that a forecaster wishes to make a 5-year prediction for cumulative AIDS cases and that 35 percent of HIV-infected persons contract AIDS within 6 years; if, as of a year ago, 2,000 were infected and, of these, 100 (5 percent) have already been diagnosed with AIDS, then in 5 more years, an additional 600 (30 percent of 2,000) are expected to contract the disease—for a predicted cumulative total of 700 cases in 5 years from the forecast date.

2. Data Sources and Assumptions

Two empirical data sources underlie back-calculation forecasts: (1) the national surveillance data on trends in AIDS cases and (2) various studies estimating the "time-to-AIDS" (that is, the time from HIV infection to conversion to clinical AIDS). Both these types of data are employed in conducting the back calculations that project earlier trends in HIV infection. Then, the time-to-AIDS estimates are used again to translate the existing HIV trends into predictions of new AIDS cases.

The back-calculation method is limited to forecasting new AIDS cases among persons who are already infected with HIV; it does not include prediction of new HIV infections. Thus, unless another method (such as extrapolation) is used to estimate new HIV infections, back calculation forecasts assume no new HIV infections. Obviously, the assumption of no new infections produces a lower forecast. For this reason, Brookmeyer and Gail termed their 1986 forecast the "minimum size" of the future epidemic.

3. Variation in Forecasts

Numbers of cumulative AIDS cases predicted through 1991 by means of the back-calculation method range from a low of 84,000 or 116,000 (the lower bounds of Brookmeyer and Gail's 1986 and updated 1988 forecast ranges) to almost 300,000 (Harris's forecast through the fourth quarter of 1991).

4. Differences in the Models and "Best Estimates"

Back-calculation forecasting models differ primarily in terms of values used for the time-frame of disease development (time-to-AIDS distribution). The time-to-AIDS parameter is a key determinant of the estimated sizes of HIV-infected cohorts in earlier years. Generally, given an observed number of AIDS cases, the longer the time-to-AIDS, the larger the estimated sizes of earlier cohorts—and the greater the proportion of these cohorts not yet diagnosed as AIDS cases.

For example, Brookmeyer and Gail's 1986 best-estimate forecast (121,000 cases by year-end 1991) is based on their best estimate of the incubation period; using studies available as of 1986, they estimated a time-to-AIDS distribution with a median of 4.3 years.[10] Harris (1987) also used a relatively short incubation period (median 5.5 years).

Back-calculation forecasting models also differ according to whether a supplemental method was used to allow prediction of new HIV infections—and thus whether the forecast is expanded beyond those AIDS cases that are expected to result from persons who are already infected with HIV. For example, Brookmeyer and Gail's (1986) forecast of cumulative AIDS cases for 1991 is based on the assumption that no new infections will occur after 1985. By contrast, both Harris's best-estimate forecast and Brookmeyer and Damiano's 1988 upper-bound forecast include AIDS cases that are expected to result from future HIV infections predicted by means of a supplemental method.

It is interesting to note that if a fairly long period of time usually elapses between the point of infection and the point of conversion to clinical

[10]The 4.3-year estimate of the incubation period applies only to HIV-infected persons who will eventually develop AIDS. In their updated study, Brookmeyer and Gail (1988) varied the incubation period distribution, using medians of from 4.3 years to 8 years, which yielded higher estimates. In addition, using data from subsequent studies of the incubation period, Brookmeyer and Damiano (1988) forecast well over 200,000 cases by year end 1991.

AIDS (see chapter 4 of this report), then the assumption of no new infections does not have a very great impact on relatively short-term forecasts.[11] By the same token, however, the longer the true time-to-AIDS, the less reliable the back-calculation estimates of the most recent levels of new HIV infection. For example, looking at current data on new AIDS cases, if the incubation period is usually long, the new AIDS cases would include only a tiny portion of the new HIV infections that occurred during the past year; hence, it would be difficult to estimate the full size of last year's newly infected cohort.

5. Bases for Forecast Ranges

Brookmeyer and Gail's (1986, 1988) predicted ranges are based on alternate assumptions regarding the time-to-AIDS distribution. In Brookmeyer and Damiano's (1988) forecast, the predicted range takes account of statistical error; additionally, the lower bound assumes no new infections whereas the upper bound assumes new infections will continue at the same rate as has recently been calculated. Harris's range is similarly based on alternative assumptions of no new HIV infections versus a continuing (extrapolated) HIV infection rate.

Macro-Simulation Forecasting

1. General Description and Logic of Method

These models simulate epidemiological processes at the society-wide or "macro" level—without addressing the individual-level events that combine to determine the epidemic trend. Two steps are typically involved. First, distributions are used to model or project the spread of HIV infection during past, present, and future years. Second, having projected HIV infections (including future infections), the macro-simulation forecasters proceed to estimate the numbers of AIDS cases that will result from these infections as of a specific future date. In other words, like the back calculation forecasting method, the second step of the macro-level simulation method consists of combining the estimated number of HIV infections with information on the time-to-AIDS distribution in order to predict AIDS cases for selected future years.

[11] Harris conducted a supplemental analysis in which an extrapolation of infection trends indicated that 30,000 new infections could be expected to occur and to convert to AIDS by spring of 1991. Harris's "best estimate" of 250,000 by spring 1991 includes cases stemming from these new infections as well as the 220,000 cases based on "back calculation."

Unlike back-calculation models, however, macro-level simulation models typically predict future HIV infections, and they include in their forecasts AIDS cases that are expected to result from these new infections. Also unlike back-calculation models, macro-level simulations can use distributions that have built-in alternative scenarios for the future course of the epidemic. For example, in Artzrouni's macro-level simulation model, HIV-infected persons decrease or entirely cease risky behaviors when they contract AIDS.

While risk-transmission groups have been examined separately in some macro-level models, other demographic groups (such as geographically defined subpopulations) have not been examined.

2. Data and Assumptions

As was the case for back-calculation forecasts, the primary empirical data sources used in these macro-level simulation models are (1) the national AIDS surveillance data and (2) various studies estimating the time-to-AIDS. Both information sources may be used to describe HIV infection levels in future years. However, in choosing the form of the trend/distribution for past—and especially for future—HIV infections, macro-level models rely not only on data but also on key assumptions about the nature of the epidemic. Assumptions made by various macro-level models include the point in time when HIV infection trends will peak or have already peaked, the rate at which new HIV infections are currently occurring and whether this rate is expected to increase or decrease, whether the epidemic will be contained within current high-risk groups (that is, within the homosexual male and intravenous (IV) drug user populations) or may spread into the non-drug-using heterosexual population, and how far in the future is the time when new infections eventually cease. Data on the time-to-AIDS are typically used to predict the number of AIDS cases that are expected to result from these projected levels of HIV infection.

3. Variation in Forecasts

The four forecasts based on macro-level simulations vary considerably—ranging from Artzrouni's lower-bound estimate of 143,000 AIDS cases to Pascal's upper-bound estimate of 750,000 cases. Considerable variation exists both within the ranges specified by individual forecasters (notably, Dahlman et al., whose forecast range goes from a lower bound of 241,000 to an upper bound of 304,000) and across the best-estimate forecasts, which go from Artzrouni's forecast of 159,000 to the Dahlman et al. forecast of 259,000 AIDS cases and to the highest value (400,000 for Pascal).

4. Differences Across Models and "Best Estimate" Forecasts

The specific assumptions made regarding the spread of HIV infection differ across the various macro-level simulation forecasting models.

Artzrouni assumes that the new-infection rate is a decreasing function of the cumulative number of HIV infections; using the national surveillance data together with a model based on this assumption results in an estimated epidemic in which new infections peaked in 1983. The results of his model are linked to two key notions: (1) virtual "containment" of the epidemic within high-risk groups (male homosexuals and IV drug users)—that is, little or no expansion of the epidemic in the non-drug-using heterosexual population—and (2) relatively early "saturation" of the high-risk groups (homosexuals and IV drug users). Within these parameters, Artzrouni's best estimate is based on a time-to-AIDS distribution with a median of 8 years.

Cowell and Hoskins, like Artzrouni, base their forecasts of AIDS cases on the absence of an epidemic among non-drug-using heterosexuals. However, they see the peak of new HIV infections occurring between 1987 and 1991. Cowell and Hoskins' best-estimate forecast of AIDS cases is based on what they consider a most likely scenario concerning HIV spread: new HIV infections peaking in 1988-89 (at over 200,000 new infections per year) and declining to zero by 1997.

Dahlman's best estimate prediction is based on a combination of various assumptions, including (1) limited spread in the heterosexual population and (2) over one million persons being currently infected.[12]

5. Basis of Forecast Ranges

Artzrouni's predicted range is based on differing assumptions regarding the time-to-AIDS. (Median incubation periods range from 4 to 12 years.)

Cowell and Hoskins' predicted range is based on varied assumptions about the point at which new infections will cease—going from immediate cessation (no new infections as of the time of the 1987 forecast) to no cessation until the infection spreads through 100 percent of the high-risk groups.

The predicted range of AIDS cases forecast by Dahlman et al. is based on varied assumptions about (1) the time-to-AIDS distribution and (2) the current level, and the spread, of HIV. Specifically, Dahlman et al.'s lower

[12]With new infections having peaked in 1986-1987 (according to Dahlman's model), this translates into a peak in new AIDS cases that will occur around the year 2000.

and upper bounds for AIDS cases are based on differing possibilities concerning the spread of the HIV infection into the heterosexual population; HIV is alternatively assumed to have already (that is, as of 1986) reached about 800,000 persons or over 2 million persons.

The high figure for AIDS cases, developed as part of Pascal's cost analysis, is based on two earlier estimates: first, an earlier CDC estimate that "current" (1986) HIV infections numbered 1.5 million and, second, Pascal's rough estimate (based on Johnstone, 1986) that half of those infected in 1986 would convert to AIDS by the end of 1991.

Micro-Level Simulation Forecasting

1. General Description and Logic of Method

Micro-level models involve simulation of individual risk behaviors, HIV transmission from infected to previously uninfected persons, and the development of the disease (AIDS) among those infected with HIV. In this way, the spread of HIV infection is modeled for past, present, and future years, and future AIDS cases are forecast. Micro-level modeling requires estimates of the size of the various risk groups (such as homosexuals, IV-drug users, and non-drug-using heterosexuals) and of the frequency of corresponding risk behaviors, as well as of the "transmission efficiencies" or probabilities that HIV transmission will occur when an uninfected person becomes exposed to the virus.

Micro-modeling of HIV transmission also involves specifying the "mixing" of individuals within or across the risk groups (for example, the number of homosexual partners a male has or the percentage of non-drug-using heterosexuals who have sexual contact with IV-drug users). Mixing behavior can also be defined in terms of racial, geographical, or other kinds of population subgroups. Finally, in addition to modeling HIV transmission, micro-level models consider disease development (progression or conversion to AIDS) among HIV-infected persons. Disease development is linked back to HIV spread in terms of the decreasing tendency of an infected person to continue the risk behavior as the disease develops.

Because of their detailed depiction of the individual-level processes involved in the HIV epidemic, micro-level simulations are useful for producing a host of policy and research-related information, such as examining and/or comparing the likely or potential effects of the different kinds of possible interventions on different components of the epidemic. However, within the context of this report, the primary relevance of these models is their use in producing forecasts of numbers of cases for specific future dates (here, year end 1991).

2. Data and Assumptions

Micro-simulation models use not only the national surveillance data for AIDS (both for the nation as a whole and for various demographic and risk groups) and studies estimating the time-to-AIDS, they also draw upon what studies exist concerning the size of the risk groups, the frequency of risk behaviors, the likelihood of HIV transmission via specific risky events, and so forth. But the information currently available on risk groups, risk behaviors, and HIV transmission is extremely limited. As a result, micro-level simulation models that forecast AIDS cases must, at present, make numerous explicit assumptions about individual behavior and events. The most general (implicit) assumption associated with micro-simulation forecasts as a group is the feasibility of modeling the epidemic at the individual-behavior level despite the limited information available.

With respect to risk-group sizes and frequency of risk-group behaviors, transmission efficiencies, and mixing of persons, micro-level modelers have set initial parameters for these components of the epidemic based on assumptions or on what limited data were available, or a mixture of the two. Kanouse, Cardell, et al. drew upon numerous small or inconclusive studies, as well as upon personal communications with knowledgeable persons. For example, their estimate of 1.2 million IV-drug users who share needles is based on admittedly flawed estimates of the prevalence of heroin use and essentially no quantitative data on either route of administration or needle-sharing among IV users. For other parameters, micro-modelers must draw upon now outdated studies, notably the Kinsey study of sex behavior (Kinsey, Pomeroy, and Martin, 1948).

Subsequently, these forecasters have adjusted the values for some of these interrelated components so that their models' outputs or results would match the national surveillance data for the early to mid-1980's. In other words, these forecasters have used surveillance data as a way of adjusting or calibrating the values they initially selected for these individual-behavior parameters or transmission efficiencies. The two are interrelated: Plumley points out that the seemingly arbitrary values he chose for transmission efficiencies were considered in conjunction with behavioral frequencies before adjusting those frequencies to produce output matching existing trends in the national AIDS surveillance data. As a result, Plumley concludes that "to the extent that the [transmission efficiencies] are overstated, the frequencies of [risk activity] will be automatically understated."[13]

Neither of the two micro-level models includes the number of sex or drug partners that various persons may have. However, Kanouse, Cardell, et al. maintain that they tried to account for the effects of "autocorrelation in partner choice"—that is, a person with two partners in a specific time interval cannot himself infect more than two people during that time—by reducing the average level of infectivity in their transmission-efficiency component.

Micro-level modelers do not make sweeping epidemic-wide assumptions. For example, they do not assume that new HIV infections will be contained within the current high-risk groups or that the "peak" of new HIV infections is likely to occur, or to have occurred, in a particular year. (The "output" of the micro-models indicates, however, that some expansion into the heterosexual population is likely to occur and that, at least in other groups, the peak of new HIV infection is either just past or is growing at a slower rate than previously.[14])

3. Variation in Forecasts

The two micro-simulation models (Plumley and Kanouse, Cardell, et al.) yield near-identical forecasts for 1991 (about 250,000). Plumley's predicted range is not wide (251,000 to 256,000).

[13]Plumley, 1988, p.3.

[14]Kanouse, Cardell, et al. predict that: "As of the end of 1987 the model projects that there were approximately 800,000 people infected. The annual rate of growth in the (cumulative) size of the infected population at year end is projected to be about 20%, with the most rapid growth occurring among heterosexual men and women (33% and 26%) and among bisexual men (29%). Conversely, the lowest rates of growth are in the populations with the most rapid growth rates early in the epidemic, including homosexual men who are IV needle sharers (6%), homosexual men who live in New York or San Francisco (8%), and IV needle-sharers in New York City (5%). The marked slowing in the rate at which infection is estimated to be spreading in these high risk populations mostly reflects exhaustion of the most susceptible members, augmented to some extent by the effects of recent changes in behavior" (pp. 15-16). Similarly, Plumley puts the peak for new homosexual/bisexual infections in the recent past (1985), for drug users in the present (1987-88), and for heterosexuals in the future (heterosexual women, 1987-89; men, 1993-95).

4. Differences Across Models and "Best Estimates"

With regard to mixing factors, the Kanouse, Cardell, et al. model limits contacts between persons according to their age group and geographic location. By contrast, Plumley imposes racial boundaries; specifically, Plumley assumes there is no mixing across racial lines with respect to the various risk behaviors.

With respect to transmission, Kanouse, Cardell, et al. model variation in infectivity as HIV-infection progresses towards clinical AIDS. Plumley does not.

5. Bases for Forecast Ranges

Plumley's range is based on possible future changes in sex behavior, drug behavior, and also in mixing behavior—that is, the possibility that non-drug-using heterosexuals will limit their heterosexual contacts with bisexual males and with IV-drug users. With respect to future years, Plumley varied the frequencies of risk behaviors in a sensitivity analysis. However, future changes in behavior related to HIV-transmission would have minimal impact on short-range forecasts of AIDS cases (for example, 1988 to 1991) owing to the apparently lengthy period of time that elapses between the point of HIV infection and the point of conversion to clinical AIDS.

Data Quality: National AIDS Surveillance Data and Studies of the Time-To-AIDS

As is clear from chapter 3, the national AIDS surveillance data on caseload trends are an important ingredient for all existing AIDS forecasts. Micro-simulation forecasting models also rely on the surveillance system for data on risk groups and demographic subgroups, and macro-simulation forecasters base their assumptions, in part, on the risk-group data. Further, models that use the time-to-AIDS to estimate HIV infections are particularly sensitive to estimates of the time-to-AIDS. Thus, the quality of these data are critically important to the accuracy of forecasts.

Our review of the national AIDS surveillance data reveals that they are clearly far superior to many other kinds of surveillance data, such as medical reports on syphilis in the late 1960's.[1] But surveillance data were not intended to be used in forecasting, and when they are used for this purpose, numerous potential and documented data problems can arise. If not recognized, estimated, and adjusted for in AIDS forecasts, these data problems can bias projections for cumulative cases through 1991—both by underrepresenting and by overrepresenting existing or past cases. Of the 13 problems identified in the course of our review, we judge that 8 will lead to forecasts that are too low, 2 will result in forecasts that are somewhat high, and 3 will interject discontinuities into the trend data.

The adjustments used by CDC in its most recent AIDS forecast recognize lags in reporting and apparently imply that, aside from reporting lags, the surveillance data used by forecasters encompass 84 percent of all AIDS cases.[2] But the problem is larger than this, because the CDC adjustment takes account of few known biases. When a larger set of biases that can over or underrepresent the true size of the epidemic are examined, their potential net effect—in the absence of compensatory adjustments—is a sizable underrepresentation of the epidemic. Specifically, based on existing studies, we estimate that of all cases of AIDS and

[1]In fact, a report of a recent conference on AIDS modeling indicated that the quality of the national AIDS surveillance data was "good." See A National Effort to Model AIDS Epidemiology: Report of a Workshop Held at Leesburg, Virginia, July 25-29, 1988 (Washington, D.C.: Office of Science and Technology Policy, Executive Office of the President, 1988).

[2]CDC's inflation factor of 1.19 used in its "Charlottesville" forecast (see U.S. Public Health Service, 1988a) is equal to 100 over 84. From this, one would infer that for every 84 cases included in the forecasting analysis, there were thought to be 100 actual cases. That is, 16 of every 100 cases had not been captured in the data.

other fatal HIV-related illnesses,[3] one third may not have been captured in the national surveillance data used by most forecasters.

Although it is clear that a significant underrepresentation has existed in the national AIDS surveillance data, there are insufficient data available to estimate all sources of potential bias, and more methodological studies are needed. Limited resources have been available at CDC for the surveillance of AIDS cases and for assessments of data completeness, because of competing priorities in public health programs.

Other problems in the AIDS surveillance data apparently minimize the number of cases categorized as heterosexual risks and have inadvertently masked trends showing increases in heterosexual-transmission cases.

Problems in estimating the time-to-AIDS distribution stem from the fact that the epidemic is still new and the incubation period is long and variable.[4] As discussed below, underestimates of the true time-to-AIDS seem more probable than overestimates, at least in early studies, although considerable uncertainty is associated with these data.

Quality of the National AIDS Surveillance Data

Background

Surveillance systems rely upon physicians and other health care professionals to send in case reports to a central registry;[5] these systems have often failed to capture all cases. This is in part because such systems are not completely controllable by the agencies that maintain registries.

[3]The term "AIDS and other fatal HIV-related illnesses" is used in this report to refer to both (1) cases of AIDS that qualify for CDC's current definition (a list of specific qualifying illnesses that has been expanded over time) and (2) other HIV-related illnesses of which patients have died. As discussed below, CDC expanded its definition of AIDS in September 1987, but an estimated 9 percent of HIV-related deaths are from illnesses that are still not included in CDC's list.

[4]The disease was first recognized in this country about 10 years ago, and current estimates of the median incubation period are about 8 to 10 years.

[5]See Thacker and Berkelman (1988) for a discussion of public health surveillance in the United States. See appendix I of this report for a description of CDC's AIDS surveillance system prepared by that agency.

Underreporting by the medical community has traditionally been serious for sexually transmitted diseases. One national study (Fleming et al., 1970) estimated that only a small percentage—12 to 19 percent—of diagnosed infectious syphilis cases was actually reported to authorities by private physicians in the United States. This finding calls into question the use of surveillance data for research or forecasting purposes—unless it is possible to assess and then adjust for data problems such as underreporting. As epidemiologists pointed out almost two decades ago:

"Generally the number of cases of notifiable diseases reported is far lower than the number occurring, and the proportion varies with time and place, as well as with the disease. This deficiency may not seriously impair the value of the system for control purposes, since the beginnings of an epidemic may be apparent in a trend, even if only a small proportion of cases is being reported. However, the incompleteness seriously limits the use of such data in determining the distribution of a disease in a population" (MacMahon and Pugh, 1970).

Essentially the same message was voiced by Sydenstricker (1988) who also pointed to differential completeness of case counts by demographic subgroups. But, perhaps because other data are unavailable, virtually every forecast of the AIDS epidemic to date--including the CDC forecasts—has relied upon AIDS surveillance data.

Our Approach to Assessment

Although underreporting is the most widely recognized problem in surveillance case data, it represents only one of many potential sources of bias in forecasts of the epidemic. To systematically identify biases affecting the quality of national surveillance data underlying AIDS forecasts, we used a conceptual framework consisting of the various processes involved in the AIDS surveillance system. As shown in table 4.1, several specific steps are involved in case gathering, case reporting, and classification or tabulation. This framework guided our interviews at CDC and our literature review, thereby facilitating the systematic identification of documented or potential biases. Specifically, we asked what problems might occur during each phase of the national surveillance process. Once a complete set of potential problems had been identified, we sought information on the likely size of each bias and attempted to estimate the potential net effect of all biases. We also examined problems in the national surveillance data for subgroups and risk groups.

Table 4.1: CDC AIDS Surveillance System: Activities Following the Occurrence of a Health Event, by Stage[a]

Stage	Activity
Case-gathering process	CDC list of illnesses determines which types of health events will qualify as AIDS cases.
	Interface between medical system and community determines when (or if) persons with qualifying AIDS illnesses will be assessed by physician, coroner, or other medical expert.
	Medical assessment—with or without HIV and other laboratory tests—results in a specific (correct or incorrect) diagnosis that is written into the medical record.
	CDC diagnostic test requirements determine which diagnoses will be acceptable for counting in their system.
Case-reporting process	Active versus passive surveillance systems influence when (or if) the physician or other health worker reports the AIDS diagnosis to local health authorities (who subsequently forward the information to CDC).
	Questions about AIDS risks on the case-report forms provided by CDC determine the kinds of experience that are reported as exposure risks.
Case-classification process	CDC rules for categorization determine which types of risk experience result in specific risk-group classifications.

[a]See appendix I for a fuller description of the CDC AIDS surveillance system.

Biases in the AIDS Surveillance Data: National Level

Thirteen biases or problems affecting national surveillance data were identified within the case-gathering (that is, case definition and medical-diagnosis) and case-reporting processes. Some of these problems stem from the changing definition of what constitutes an AIDS case—that is, CDC's listing of the specific HIV-related illnesses that qualify as "AIDS," which has been expanded over time. Other data problems have resulted from the diagnostic process or from a disjuncture between prevailing diagnostic practices and CDC's diagnostic-testing requirements. Still other problems occur in the reporting of diagnosed cases. The varied effects of these different problems on the national surveillance data include undercounts, delayed counts, overcounts, and data discontinuities.[6]

Undercounts and Delayed Counts

As shown in table 4.2, the majority of the problems that have affected national surveillance data (8 of 13 problems) contributed to undercounts

[6]CDC officials objected to our use of the term "count" because they believe it conveys the implication that the surveillance system is simply a mechanism for counting cases. We do not intend this implication; rather, we recognize the complexity of the system as shown in table 4.1, and we use the terms undercount, delayed count, and overcount for ease of communication in alluding to the extent to which the system captures and records all relevant cases.

or delayed counts—and thus, when uncorrected, to low forecasts—of the number of persons with AIDS and other fatal HIV-related illnesses. Two undercount problems were associated with CDC's definitions of an AIDS case, two other undercount/delayed-count problems concerned whether or when diagnoses occurred in the medical community, two more undercount problems stemmed from a lack of fit between medical practices and CDC requirements for diagnostic testing requirements, and two additional undercount/delayed-count problems occurred in the case-reporting process.

Table 4.2: National AIDS Surveillance Data: Thirteen Problems (8 Undercount/Delayed Count, 2 Overcount, and 3 Data-Discontinuity Problems), by Source

Source	Undercount/delayed count problems	Overcount problems	Discontinuity problems
CDC's list of qualifying AIDS-related illnesses	Of all cases of AIDS and other fatal HIV illnesses: 1. Some did not qualify as AIDS until September 1987[a]. 2. Others still do not qualify as AIDS (pre- or post-September 1987).		11. CDC lengthened its list of qualifying AIDS illnesses.
Diagnosis of AIDS by medical community	Of qualifying AIDS cases: 3. Some were never diagnosed. 4. Others were diagnosed late.	9. Some cases were erroneously diagnosed as AIDS (false positives).	
CDC's test requirements for diagnosis	Among diagnosed cases of qualifying AIDS illnesses: 5. Presumptive diagnoses with HIV tests were not accepted until September 1987.[b] 6. Presumptive diagnoses without HIV tests are still not accepted (pre- or post-September 1987).		12. CDC liberalized its diagnostic requirements.
Report of diagnosed cases to CDC	Of acceptably diagnosed AIDS cases: 7. Some were never reported. 8. Others were reported late.	10. Some cases were counted more than once (double counts).	13. New late reporting occurred in response to active surveillance or definition change.

[a] "Wasting syndrome" and dementia, for example, did not qualify as AIDS illnesses until September 1987.

[b] Pre-September 1987, all qualifying HIV-related illnesses required diagnostic tests confirming illness; post-September 1987, presumptive diagnoses were accepted if HIV tests were performed.

These eight problems involve the following specific types of cases: (1) cases in which the HIV-related illness, such as wasting syndrome, was not defined by CDC as a qualifying AIDS illness until September 1987; (2) other fatal cases that are still not officially defined as AIDS because the specific illness is (still) not included in the CDC case definition, even though death results from HIV-related causes; (3) cases that were never diagnosed by the medical community (that is, persons with AIDS, as defined by CDC, who nevertheless die without ever having been so diagnosed even on the death certificate); (4) cases diagnosed late, as has occurred when AIDS cases were correctly diagnosed only at death; (5) cases which were reported with a positive HIV antibody test, but in which the diagnosis of a specific AIDS illness was made "presumptively"[7] and which were therefore not accepted by CDC until September 1987; (6) cases in which the diagnosis of a specific AIDS illness was made presumptively without a positive HIV antibody test and which are still not defined by CDC as acceptably diagnosed cases; (7) cases that were never reported, that is, failures of the medical community to report the cases that they diagnosed as AIDS; and (8) cases reported late, that is, lags—again on the part of the medical community—in preparing and sending to local authorities reports of cases that have been medically diagnosed (including some trends toward lengthening lags—or time between the diagnosis date and the report date—due to "reporting fatigue").

In September 1987, CDC attempted to correct undercount problems 1 and 5 by expanding their definition of an AIDS case. Specifically, they lengthened their list of HIV-related illnesses that qualify as AIDS cases, and they liberalized their requirements for diagnostic tests for specific illnesses in those cases where HIV antibody test results were available. While many more cases were counted after September 1987, the new definition still did not encompass all cases that had been excluded under the old definition. (As attested to by problems 2 and 6, above, some types of cases were captured neither before nor after September 1987.) Further, the definition changes introduced data discontinuities, which are discussed

[7]Presumptive diagnoses are those in which the physician does not conduct specific tests (such as those based on a patient's bone marrow) in order to confirm his diagnosis of the specific AIDS illness.

in a subsequent section of this chapter; as a result, forecasters have generally limited themselves to data on cases diagnosed before the definition change.[8]

Overcounts

A minority of the biases affecting national surveillance data (2 of 13 biases) tend to overcount—and thus potentially overforecast—AIDS cases. The two data problems that, if uncorrected, result in overcounts are false-positive diagnoses of AIDS cases and double-counting of cases (which can occur when, for example, two different states report the same case of AIDS). These overcount problems derive from the case-gathering and case-reporting processes.

Data Discontinuities

Data discontinuities that could bias the most recently made forecasts stem from (1) changes in the list of illnesses that CDC defines as reportable AIDS cases, (2) changes in CDC's diagnostic requirements, and (3) a new form of late reporting in which batches of cases that had been diagnosed in the past were now suddenly being reported from some local areas (due to recent changes such as increased CDC surveillance activities and newly qualifying illnesses).

For the most part, these data discontinuity problems have resulted from definition changes occurring during 1987. As previously noted, even the most recent national forecasts reviewed here (notably, CDC's 1988 forecast) have not used cases diagnosed subsequent to the September 1987 definition changes; this was, in part, to avoid data discontinuity problems.

[8]With three exceptions, forecasters limited their analyses to data in which cases were both (a) diagnosed before July 1987 and (b) reported before September 1987, when the definition changed. The first exception is CDC's most recent (1988) forecast, which included only cases diagnosed as of July 1987 and allowed subsequent reports of such cases only if they involved an illness that met the "old" (more restricted) definition; the diagnoses did not have to meet the stricter "old" testing requirements, however. The second exception is Hellinger's forecast, which included all reports through October 1987 (the first month of the new definition). The third exception is Brookmeyer and Damiano's forecast, which allowed only cases diagnosed before July 1987 but included subsequent reports of such cases that came in up to January of 1988.

Sizes of Undercount, Delayed Count, and Overcount Problems

Data are limited on the sizes of the various undercount and overcount problems at the national level.[9] Rigorous national studies have not been conducted, and despite CDC's stated interest in pursuing such work, resources have been limited.[10] Nevertheless, the existing studies and estimates clearly indicate that undercount problems are considerably more serious than overcounting problems. Not only are undercount problems more numerous than overcount problems, but some of the undercount problems appear to be sizable.

The limitations of currently available assessments of the national AIDS surveillance data have meant that the sizes of some biases could be estimated, at best, on the basis of local studies done at isolated points in time. Any such effort is plagued by questions like the following: (1) To what extent does an assessment of a particular data bias in a certain local area apply equally across all areas nationally, or even across all areas defined as "similar"? (2) Do the problems that have been assessed for only those groups (such as drug users) in which these problems are thought to predominate also occur in any other groups? (3) To what extent are biases that have been estimated only in a particular year representative of earlier and later years—or have these biases increased or decreased across time? Dealing with such questions on a case-by-case basis, we used assumptions and post hoc analyses (described later in this chapter) to make rough estimates of national-level biases in data used by forecasters and to eliminate overlap between estimates for different (but related) problems. Only one problem had to be estimated solely on the basis of limited expert opinion at CDC and at the local level.

[9] A number of methodological studies have assessed various biases in the surveillance data at the local level. Other studies are in the planning stage at CDC. But, through 1988, existing assessments have typically been based on small samples and conducted in particular cities or have been based on a sample consisting of only a single risk group (for example, drug users) in one city. Comparing available assessments of surveillance data suggests that biases vary considerably across geographic locations, risk groups, and points in time. The limitations of existing studies thus make it difficult to apply the results to national-level data. In addition, one of the surveillance-data biases identified in our review—cases that were never diagnosed by the medical community—has thus far not been empirically assessed in any area: CDC noted, in response to a draft of this report, that they are planning to conduct such a study. Finally, no national study has attempted to comprehensively examine sources of bias so that their combined size could be estimated. A study with this goal is now in the analysis stage in New York City, according to our discussions with surveillance staff there.

[10] More rigorous national assessment of the surveillance data was called for in the recent report of the conference held in Charlottesville (U.S. Public Health Service, 1988a) as well as in CDC's 1990 budget request.

As summarized in table 4.3, previous studies or estimates of particular problems (produced chiefly by staff at CDC or by state or local governments in New York and other areas) have provided a variety of "percentages" of cases not counted—each due to a single problem. One of the difficulties in interpreting these data is that the percentages are based on different denominators. Therefore, in discussing the nature and estimated size of each undercount and overcount problem, we present the basis for each denominator of "percentages" of cases not captured in the surveillance system.

Table 4.3: National AIDS Surveillance Data Used by Forecasters: Estimated Problem Size and Source of Estimate for Each Undercount/Delayed Count and Overcount Problem

Type of problem (from table 4.2)	Estimate of problem size	Source of estimate
Undercount/delayed count problems		
Of all relevant illnesses (that is, AIDS and other fatal HIV-related illnesses):		
1. Some were not included on CDC's list of qualifying illnesses until September 1987.	6% of all cases of AIDS and other HIV-related illnesses	CDC data tabulation (after September 1987) and expert opinion
2. Others are still not included on CDC's list of qualifying illnesses (pre- or post-September 1987).	9% additional	New York City empirical study of drug-user deaths (1986) and expert opinion
Of qualifying AIDS illnesses:		
3. Some were never diagnosed.	10% (?) of all qualifying AIDS illnesses[a]	CDC and local expert opinion (no empirical data)
4. Some were diagnosed late.[b]	At least 12.3% of all reported cases	CDC data tabulation (1988)
Of diagnosed qualifying illnesses:		
5. Presumptive diagnoses with HIV tests were not accepted until September 1987.	12% of all diagnosed qualifying illnesses	CDC data tabulation (after September 1987)
6. Others without HIV tests were still not accepted (pre- or post-September 1987).	4% additional	New York City unpublished death certificate study (1986/1987)
Of acceptable diagnoses of AIDS cases:		
7. Some were never reported.	11% of all properly diagnosed cases	CDC and others' empirical study of death certificates (4 cities, 1985)
8. Others were reported late.[b]	17% of all properly diagnosed cases	CDC data tabulations (1986)
Overcount problems		
Of reported cases:		
9. Some were erroneously diagnosed (false positives).	0 to about 3% of reported cases	CDC empirical study of cases with no identified risk (1987)
10. Some were reported more than once (double counts).	1.33% of reported cases	CDC data tabulation (1988)

(continued)

[a]A question mark is indicated because this estimate of problem size is extremely uncertain due to lack of empirical data

[b]Delayed count problem. cases are eventually diagnosed and reported

Sizes of Undercount/Delayed Count Problems: Rough Estimates

Illnesses deriving from HIV (such as wasting syndrome)—but not officially defined as AIDS until recently because of strict CDC definitions—represent a substantial percentage of all cases of AIDS and other fatal HIV-related illnesses. Specifically, tabulations by CDC conducted since the September 1987 definition change indicate that 14 percent of new cases involve illnesses that would not have been defined as AIDS under the old definition. Assuming that in half of these cases the patients will eventually develop other illnesses that would qualify under the old definition, CDC forecasters have estimated that about 7 percent of cases meeting the current definition would never have qualified under the old definition (problem 1 in table 4.3). Calculated as a percentage of the larger universe of relevant cases (that is, all cases of AIDS and other fatal HIV-related illnesses), the problem is estimated at 6 percent.[11]

An estimated additional 9 percent of all cases of AIDS and other fatal HIV-related illnesses are still not defined as AIDS by CDC (problem 2 in table 4.3). Most of the work identifying this problem has been done in New York City. The various studies have focused on the increasing numbers of young narcotics users who are HIV positive and who die of pneumonia, sepsis, tuberculosis, and other infectious diseases—but who never develop any of the illnesses on CDC's AIDS definition list (see Stoneburner et al., 1988a; Stoneburner et al., 1988b; Selwyn et al., 1988). Additional evidence is provided by cohort studies indicating that HIV-negative drug users are not dying of bacterial pneumonia or sepsis (Selwyn et al.,1988). Although the problem of HIV-related deaths that do not qualify for CDC's current definition of AIDS clearly exists, it is difficult to estimate its size.

One quantitative study (Stoneburner et al., 1988a) has tracked drug user deaths in New York City over time, employing the assumption that intravenous (IV) drug use has not increased or decreased from the early to the mid-1980's. Under this assumption, the expected number of drug-

[11]Given that 7 percent of CDC's currently captured cases meet only the new CDC definition, if one assumes that such cases occur with equal frequency (7 percent) among all the captured and uncaptured cases that qualify under the CDC's current list of AIDS illnesses, then the 7 percent applies to 91 percent of the total universe—that is, to all cases except those covered by problem 2. Thus, to express problem 1 as a percentage of all cases in the universe, one would take 7 percent of 91 percent (multiplying: .07 X .91 = .06), or 6 percent of all cases.

user deaths would remain constant,[12] except for AIDS cases among drug users. "Excess deaths" among narcotics users were calculated, and the study estimated that if the excess deaths among drug users, which appeared to be due to HIV-related illnesses, were added to those counted as AIDS deaths, AIDS fatality "would be 50% greater overall, and 134% greater among IV drug users" in New York City (p. 242).

Our analysis of figures provided in the Stoneburner et al. (1988a) death-records analysis showed that of the narcotic deaths that appeared to be due to AIDS or other fatal HIV-related illnesses, roughly 50 percent had not been diagnosed as AIDS cases in official medical records.[13] By using our framework to identify specific problems that might have contributed to this 50 percent undercount, we isolated three problems that are logically relevant: problems 1, 2, and 3 in table 4.3. Problems 1 and 2 concern HIV-related illnesses that did not qualify under CDC's AIDS definition either (1) before the September 1987 definition change or (2) neither before nor after the definition change. Problem 3 concerns cases involving illnesses that would meet CDC's AIDS definition but that have not been diagnosed as such. Problem 1 has been estimated to be 6 percent of all cases nationally. Problem 3 is thought to be perhaps roughly 10 percent. (See discussion of this problem below.) Therefore, problem 2—at least for the HIV-related drug-user deaths in this study—might be about 34 percent (that is, .50 - (.06 + .10) = .34). Problem 2 apparently exists primarily among drug users. Since drug users constitute about 27 percent of the national AIDS caseload (according to CDC tabulations), the

[12]This assumption is supported by the (documented) steady numbers of drug overdose deaths in New York City during this period.

[13]Roughly half (1763 of 3717) of the apparently HIV-related deaths had not been diagnosed as AIDS illnesses by the medical community (and hence were never reported to the authorities). The additional undercounting beyond 50 percent appears to be due to problems 5, 6, and 7 in table 4.3. Specifically, these problems are the underreporting of diagnosed AIDS cases to public health authorities (problem 7, "never reported" in table 4.3) and the non-qualification of presumptive diagnoses of AIDS cases (with and without HIV tests—problems 5 and 6 in table 4.3). In the Stoneburner study, of 3717 cases, 1803 were diagnosed as AIDS on the death certificate, but 757 of these 1803 had not been included in public health surveillance data.

impact of problem 2 on the national surveillance data might perhaps be as high as 9 percent (.34 X .27 = .09).[14]

Taken together, problems 1 and 2 constitute an estimated 15 percent of all AIDS cases and other HIV-related illnesses resulting in death. For purposes of this report, it is appropriate to consider the two problems as having an additive impact on the national surveillance data because although CDC addressed problem 1 via the September 1987 definition change, virtually all the forecasts reviewed for this report were limited to data on AIDS cases that had been diagnosed before the definition change.[15]

A rather different problem (problem 3 in table 4.3) concerns AIDS cases with illnesses that do meet the CDC definition but that have never been diagnosed by the medical system, not even at death. This outcome could occur in at least three ways. First, it is possible that some persons with AIDS never came into contact with the medical system prior to their deaths and, furthermore, were not assessed for AIDS at the time of death (which could be due to some seemingly unrelated event such as a drug overdose or auto accident). Second, a physician might intentionally avoid making an official or written diagnosis of an AIDS-related disease—both during the patient's life and upon his or her death.[16] A third way such an outcome might occur would be for a physician to miss the

[14]Our calculation of the size of problem 2 (the problem of fatal HIV-related illnesses still not included in CDC's AIDS definition) makes three assumptions. First, that the estimates for problems 1 and 3, given for AIDS cases nationally in table 4.3, apply to New York drug users. Second, that problem 2 does not occur at all among non-drug users. Third, that the problem occurs with equal frequency among HIV-infected drug users in New York (where the study was conducted) and among HIV-infected drug users residing in other areas.

Because the percentage of AIDS cases associated with IV drug use varies by region, the size of the AIDS undercount due to problem 2 would be considerably higher in some areas. Notably, in the region defined as New York, New Jersey, Puerto Rico, and the Virgin Islands, nearly half of the reported AIDS cases are associated with IV drug abuse; this is twice the national rate. As a result, the impact of problem 2 in this region may be about twice the size of its national impact (approximately 18 percent of all cases rather than 9 percent).

[15]Subsequent to September 1987, CDC accepted "late" reports of earlier diagnoses of illnesses that would qualify only under the new, expanded definition. Thus, although limiting their analyses to diagnoses predating the definition change, a few forecasters who accepted these "late" reports have apparently not completely avoided data discontinuity issues. (See footnote 8 of this chapter.)

[16]This situation was suggested to us by the medical examiner of Dallas County. The medical examiner related an instance where one physician who had treated 17 AIDS cases resulting in death gave no indication of AIDS on more than half of these death certificates.

fact that the patient had an AIDS-related disease; this scenario might not be likely unless the patient also had another serious disease.[17]

The extent to which AIDS cases go undiagnosed apparently varies considerably across areas, being particularly low (near zero) in San Francisco (see Coleman et al., 1986), but possibly high in other areas. Two experts[18] have speculated that the number of AIDS cases that are never diagnosed might be roughly 10 percent or more; this means that—possibly—10 percent of the cases with illnesses that the CDC defines as AIDS may have gone undiagnosed. It is important to realize, however, that there are currently no empirical data on the size of this problem.[19]

Many other cases that were diagnosed as AIDS were diagnosed late (problem 4 in table 4.3). CDC tabulations indicate that 12.3 percent of all reported cases were diagnosed in the same month that death occurred; this is one type of "delayed count" (or temporary undercount) problem.

Other cases diagnosed as AIDS were not accepted by CDC because physicians did not conduct special tests to confirm that the patient actually had a specific illness that would qualify as AIDS (problems 5 and 6, combined, in table 4.3). A study of death certificates in New York City and three other cities with smaller numbers of AIDS cases (Hardy et al., 1987) found that for cases apparently diagnosed around 1984, physician failure to conduct the illness-confirming tests required by CDC probably resulted in an additional 13 percent undercounting (problems 5 and 6 in table 4.3). But because of an apparent trend towards greater numbers of "presumptive diagnoses" of AIDS cases in the medical community, this figure may have risen considerably by 1987.[20]

[17]One New York City study of autopsies of patients with AIDS-related disease(s) indicated that 75 percent of the patients had one or more additional AIDS-related diseases that had not been diagnosed or treated. (See Wilkes et al., 1988.) This suggests that if a patient has both an AIDS-related illness and another serious illness that is not deemed AIDS-related, only one of the two illnesses might be recognized, while the other might remain undiagnosed.

[18]In response to our question, an official in CDC's AIDS program speculated that the percentage of cases never diagnosed because of the three scenarios described above might be roughly 10 percent or more. An official at the local level confirmed this with a similar national estimate.

[19]CDC has informed us that they plan a "follow back" of death certificates to address this problem.

[20]A study in the state of California (Kizer et al., 1986) tracked death certificates from 1983 through the first quarter of 1985. AIDS cases not captured either because of presumptive diagnoses or because of nonreporting on the part of physicians averaged 17 percent across this period but showed a trend going from 11 percent in 1983 to 21 percent in the first quarter of 1985 (Kizer et al., p. 9). This trend could be due either to increases in presumptive diagnoses or to increases in nonreporting in California from 1983 to 1985.

In September 1987, after consulting a panel of experts and considering the information available, CDC attempted to capture most presumptive diagnoses by eliminating various requirements for tests that would confirm specific illnesses—provided that the case reports included results of HIV antibody tests. This action was apparently prompted, in part, by CDC's recognition that this source of bias seemed to be getting worse. The proportion of AIDS cases that physicians diagnosed "presumptively" (that is, without confirmatory tests) appeared to be increasing, at least in high incidence areas where physicians would logically be more familiar with the disease. Notably, in 1986 and 1987, CDC reported indications that in certain areas where presumptive diagnoses were most prevalent, they may have reached 40 or 50 percent of local cases.

These trends should be considered in estimating the number of presumptively diagnosed cases not captured in the national surveillance data used by most forecasters (that is, in calculating the combined effects of problems 5 and 6 on cases diagnosed through mid-1987). Specifically, the likely trends suggest that an increase above the 13 percent figure suggested in the Hardy study is probably needed. A more current estimate can be derived by separately addressing problems 5 and 6.

First, with respect to problem 5, CDC tabulations of cases accepted after the September 1987 definition change show that about 11 percent have been presumptive diagnoses accompanied by HIV antibody test results (problem 5). Expressed as a percentage of the smaller number of diagnosed cases in which illnesses meet the CDC's pre-September 1987 definition, the estimate for problem 5 becomes 12 percent.

Second, with respect to problem 6, presumptive diagnoses made without HIV test results are not a rarity in some areas. For example, in some areas, numerous cases may lack an HIV test because of nonavailability of testing facilities or backlogs in approved laboratories, or because the medical system is unable to provide the test-related services that are required by law in some areas (notably, the provision of pre- and post-test counseling). Additionally, as physicians have become more experienced with AIDS, they have learned to identify certain obvious or advanced AIDS cases without HIV test results.

Also with respect to problem 6, case reports may not include HIV test results even if an HIV test was conducted—in fact, the patient's "official" medical record may not contain the results of an HIV test—because of the patient's own desire for confidentiality and his or her fear of discrimination. Such motives may have dictated some patients' use of false names or code numbers for the HIV test and their reluctance to have the test results attached to their official medical records. Notably, anonymous testing (in which the person does not have to give his or her name) has been advertised by, for example, the Whitman Walker Clinic in the District of Columbia. And, in San Francisco, the recently (November 8, 1988) defeated Proposition 102, which called for physician reporting of HIV test results, created considerable controversy. In fact, according to the San Francisco Health Department, some physicians threatened to discontinue reporting AIDS cases, and indeed, before the vote defeating Proposition 102 was taken, AIDS case reports temporarily fell off by an estimated 10 percent.

Data collections to estimate the size of problem 6—lack of HIV tests or of "officially" recorded HIV test results for presumptively diagnosed AIDS patients—have not yet been published. However, a preliminary analysis of an ongoing study being conducted by New York City's case surveillance unit indicates that 5 percent of AIDS deaths occurring from mid-1986 to mid-1987 fell into this category. In obtaining a national estimate, however, the figure should be reduced at least slightly—perhaps to about 4 percent. The reason is that, based on indirect analyses at CDC, it appears that the problem of nonavailability of HIV test results has probably been less severe outside of New York (where the study was done) and California. Considering that the majority of AIDS cases have been reported from these two states, our estimate for problem 6 nationally would be reduced slightly from 5 percent to about 4 percent.

Thus, problems 5 and 6 combined may have risen from 13 percent (as estimated in the Hardy study for cases diagnosed around 1984) to an estimated level of about 16 percent (that is, .12 + .04 = .16, or 16 percent) for cases diagnosed from 1985 to 1987, as discussed above.

Cases that have never been reported to CDC (problem 7 in table 4.3), although they were diagnosed and a matter of record, represent an additional 11 percent. This estimate is based on a study (Hardy et al., 1987) of deaths occurring in 1985 in New York City and three other cities with smaller caseloads. The Hardy study found that 11 percent of the death certificates that listed AIDS or a related disease (such as pneumocystis carinii pneumonia or "PCP") as the cause of death could not be linked to AIDS cases reported to the state or local health department. The 11 percent four-city estimate is not inconsistent with an earlier estimate of 8 percent based on a New York City study (Kristal, 1985).

A considerable degree of intentional nonreporting by physicians may occur because of the stigma associated with AIDS. The plausibility of this form of underreporting seems indicated by a California death certificate study which (although it "lumped" the never-reported cases together with presumptive cases not counted by the surveillance system) found that one third of the not-counted cases had been married men, whereas only 6 percent of the counted men with AIDS were in this married group. (See Kizer et al., 1986, p.10.)

It should be noted that the percentage of never-reported cases has varied widely across areas, and estimates of local percentages also have varied according to whether they were based on death certificate studies (which have yielded lower percentages) or hospital/laboratory record checks (which have produced higher estimates of nonreporting but which may include cases that would eventually have been reported before or at the point of death).[21]

A related data problem that results in a delayed count (or temporary undercount) in the AIDS surveillance data consists of late reported cases (problem 8 in table 4.3). CDC data tabulations of reported cases indicate that in 1986 17 percent of all reported AIDS cases had been sent in to CDC 6 months or more after the date of diagnosis.

Sizes of Overcount Problems: Rough Estimates

The problems associated with overcounting appear to have been considerably less sizable than the undercounting problems discussed above. For example, a maximum of 3 percent of cases accepted and counted as AIDS by CDC may have been false positive diagnoses (problem 9 in table 4.3). Specifically, in a follow-up study of reported AIDS cases in which there was "no identified risk" (3 percent of all cases), only 3 percent of this relatively small group (that is, 3 percent of 3 percent or about one tenth of 1 percent of all cases) were found to be false positives. It is believed that false positives would occur considerably less frequently outside the "no identified risk" or NIR group. If the rate were near zero outside the NIR group, it would be near zero overall (that is, one-tenth of one percent). On the other hand, if the false positive rate were as high overall as in the NIR, the entire data set would be characterized by a 3 percent false positive rate. Thus, the range of estimates for "false positives" runs from near zero to 3 percent, but a reasonable "guesstimate" might be about 1 to 1.5 percent overall.

[21]See Conway et al., 1988; Rauch, 1986; as well as quarterly reports to CDC by states receiving cooperative agreements to conduct surveillance activities.

In addition, some correctly diagnosed AIDS cases may have been doubly counted (problem 10 in table 4.3). Specifically, CDC staff told us that computer checks for possible duplicates identified 6,000 cases, of which 5,000 were retained only as backup files to matching primary cases. The other 1,000 cases were not proven to be duplicates and were retained as separate cases in the data base. These possible duplicates represented 1.33 percent of reported cases.

Overall, undercount biases appear to have outweighed overcount biases—both in terms of the sheer number of problems and in terms of the likely sizes of their effects, but no prior comprehensive analysis has attempted to assess their potential net effect.

The Potential Net Effect of Under and Overcount Problems on National Surveillance Data Used by Forecasters

As previously stated, one of the difficulties in interpreting the estimates of various problem sizes is that the percentages are based on different denominators. Therefore, to estimate their potential combined effect, the varied percentage estimates must be converted to a constant measure—that is, each estimate must be repercentaged, using as the denominator the (estimated) total number of persons with AIDS or other fatal HIV-related illnesses. Table 4.4 shows what happens when the estimated sizes of the various undercount and overcount problems are repercentaged using a common base and combined to show cumulative effects.

Table 4.4: National AIDS Surveillance Data Used by Forecasters: Potential Net Effect of Undercount and Overcount Problems[a]

	Basis 1: using empirical studies only		Basis 2: using all information sources	
Problem sizes (from table 4.3)	**Repercentaging and calculating the cumulative effect**	**Estimated % of all cases captured**	**Repercentaging and calculating the cumulative effect**	**Estimated % of all cases captured**
Undercount problems				
Problems 1 and 2: Of all cases of AIDS and other fatal HIV-related illnesses, 6% did not qualify as AIDS until September 1987, and 9% still do not qualify as AIDS (pre- and post-September 1987).	1.00(.06 + .09) = 1.00(.15) = .15, or 15% of all cases. 1.00 - .15 = .85	85%	Same as basis 1.	85%
Problem 3: Of qualifying AIDS illnesses, 10%(?) may never have been diagnosed.	[b]	85	.85(.10) = .085 = .09, or 9% of all cases. .85 - .09 = .76	76
Problems 5 and 6: Of (diagnosed) qualifying AIDS illnesses, 12% were diagnosed presumptively with HIV-tests and were not accepted until September 1987; 4% were diagnosed presumptively without HIV-tests and are still not accepted by CDC.	.85(.12 + .04) = .85(.16) = .14, or 14% of all cases. .85 - .14 = .71	71	.76(.12+.04)= .76(.16) = .12, or 12% of all cases. .76 - .12 = .64	64
Problem 7: Of acceptable diagnoses of AIDS cases, 11% were never reported.	.71(.11) = .078 = .08, or 8% of all cases. .71 - .08 = .63	63	.64(.11) = .07, or 7% of all cases. .64 - .07 = .57	57
Overcount problems				
Problems 9 and 10: Of reported cases, 1.5% were erroneously diagnosed as AIDS, and 1.33% were double-counts.	.63(.015 + .0133) = .63(.028) = .018, or 2% of all cases. .63 + .02 = .65	65	.57(.015+.0133) = .57(.028) = .016, or 2% of all cases. .57 + .02 = .59	59
Potential net effect		**65**		**59**

[a]Delayed count problems or problems which temporarily result in an undercount of AIDS cases are not included in this analysis.

[b]No empirical study for problem 3 is available.

It should be noted that in performing these calculations, we attempted to eliminate any overlap in estimates of different biases. For example, as shown in the first "band" of table 4.4, fatal HIV illnesses not included in CDC's AIDS definition total 15 percent of all cases (pre-September 1987); therefore, the biases in the subsequent band apply only to the remaining 85 percent of cases that were included in the definition.[22] Using these procedures, we estimate that the potential net effect on the data used in existing forecasts is that the surveillance system may have captured only about two thirds of all cases of AIDS and other HIV-related fatal illness.[23]

If one also took into consideration the "delayed count" problems (cases diagnosed late and cases reported late), then the total underrepresentation of cases as of a particular point in time would be estimated as even higher. (Roughly 12.3 to 29.3 percent of cases occurring in the past 6 months would not have been diagnosed yet or, if diagnosed, not reported yet.)

Limited Resources for CDC National Assessments of AIDS Surveillance Data

Despite the difficulties in capturing many kinds of cases and the need to estimate the size of biases, limited resources have been available to the case surveillance branch of CDC's AIDS Program. In fiscal year 1988, the amount initially allocated for case surveillance was reduced by about $3 million, because of competing priorities within CDC's AIDS Program—chiefly funding of the new HIV seroprevalence surveys.[24] In CDC budget documents (dated April 7, 1988, and October 11, 1988), the revised fiscal year 1988 budget listed for case surveillance was only about one third the size of the budget listed for epidemiological/laboratory studies

[22] Not all studies were designed to isolate the problems estimated from all other problems; we attempted to use isolated effects where possible and, in other cases, to subtract out overlaps based on other estimates or assumptions.

[23] While this report was being processed, information was released in New York City (New York City Department of Health, March 1989) indicating that perhaps only about one half of all cases of AIDS and other serious HIV-related illnesses had been counted by the surveillance system in that city. Specifically, in updating city-wide projections for AIDS cases through 1993, the New York City report indicated that upward adjustments are needed to account for cases not covered by CDC's definition or not recognized by physicians and to account for underreporting of qualifying recognized cases; the two factors are estimated to account for 35-40 percent of all cases and 10-15 percent of qualifying cases, respectively. Taken together, these undercount problems would, we infer, account for roughly 50 percent of all New York's cases; that is, only half of all cases have been counted to date.

[24] Despite the cut, cooperative agreements with the states for active surveillance for AIDS were able to continue as planned on an 8-month rather than a 12-month basis. Specifically, because the agreements were scheduled to start during 1988 and to continue for 12 months, it was possible for the 1988 agreements to be funded on an 8-month basis in that year (and in that year only); in the following year, they would begin 4 months earlier and be funded for 12 months. Thus, funding would not be interrupted, but it would be possible to effect a savings for fiscal year 1988.

and only about one fourth the size of that listed for the new studies trying to measure HIV prevalence. Despite dramatic increases in the AIDS epidemic that were documented in these years, CDC's fiscal year 1989 budget for surveillance of AIDS cases remained at about the same level as the effective budget for the previous year.[25] An increase is being requested for fiscal year 1990, however.[26] The staff ceiling level (maximum full-time-equivalents or FTE's) has been increased in recent years, but actual usage of FTE's in the branch falls short of the allocated new levels.

Surveillance Data for Subgroups and Risk Groups

Differential undercounts for demographic subgroups and for risk groups can bias micro-simulation forecasts, which draw upon these data, and other forecasts that make assumptions concerning the nature of the epidemic within specific groups. The same is true for biased classification of cases in the risk groups; here, special concerns include possible minimization of the dimensions of the epidemic in the heterosexual population and limited access to data on heterosexual transmission.

Geographic Distribution

Certain metropolitan areas, such as New York City, may be plagued by special problems due to the size and distribution of the caseload in drug-using, inner-city, and poverty areas—resulting in a more severe undercount than occurs in the "average area." For example, inner-city IV drug-users may not come in contact with the medical establishment; impoverished patients may not receive the same diagnostic testing services as other patients. Conversely, other problems may be concentrated outside metropolitan areas.

For example, underreporting of diagnosed cases may be considerably more severe outside of large metropolitan areas wherever active AIDS reporting-surveillance systems have not been established by state and

[25]In some CDC budget documents, the initial fiscal year 1989 request for AIDS case surveillance appeared to be considerably greater than the revised fiscal year 1989 figure; this was only because a new activity ("behavioral surveillance") that was not a part of counting AIDS cases was initially included under the "case surveillance" heading, but subsequently listed separately.

As described in a previous footnote, 1988 cooperative agreements were funded on an 8-month basis in that year (and in that year only) to effect a redirection of funds to high-priority activities without interrupting current activites. The fiscal year 1988 8-month extramural funding was for $8.3 million, which would represent about $12.5 million on a 12-month basis. The fiscal year 1989 12-month extramural funding was for $12.9 million.

[26]CDC's budget request for fiscal year 1990 includes a substantial increase for HIV Disease Surveillance (to over $17 million in appropriations and nine additional staff). New assessments of the surveillance data are planned as part of this budget request.

local health departments working with CDC.[27] A recent study in a southern state estimated that more than one third of hospitalized AIDS patients had not been reported to the state. By contrast, in some states or local areas (such as San Francisco), underreporting of diagnosed cases appears to have been minimal. As a result, the relative dearth of AIDS cases in certain areas (notably, nonmetropolitan areas) may be somewhat exaggerated. Furthermore, because of the local input into reporting, it is possible that numerous other variations affect the validity of comparisons across geographic areas.

Risk-Group Categorization: Potential Minimization of Cases With Heterosexual Risks

Three surveillance-data problems involve AIDS cases that, while they are reported nationally, may not be counted in the appropriate risk group or groups. As a result, the number of AIDS cases typically reported as associated with heterosexual risks—4 percent of all cases reported to CDC—is apparently an underrepresentation of the true number. Risk-group categorization is a special concern among women with AIDS and perhaps also for at least some men in certain areas or groups.

The following factors—in combination—may have contributed to the apparent "under-classification" in the heterosexual category:

- incomplete information on heterosexual risks caused by health workers' skipping of items when filling out CDC's AIDS case-report forms;
- the use of stricter CDC standards for reporting heterosexual AIDS risks than for reporting other risks; and
- the nontabulation, in summary CDC tables, of a patient's heterosexual risks if other AIDS risks were also reported.

Heterosexual-Risk Items Not "Filled In" on Case-Report Forms

Many AIDS case reports are sent in to CDC with information on whether the person was exposed to heterosexual risks omitted. A special tabulation prepared for us by CDC showed that over 50 percent of the case-report forms were lacking information on specific heterosexual risks—

[27] Although CDC now has cooperative agreements with all 50 states for active surveillance, the funded efforts are generally so distributed within each state that areas and hospitals with the greatest (known) numbers of AIDS cases receive the most attention.

that is, no one had checked off "yes," "no," or even "unknown."[28] Although CDC encourages state health departments to follow up cases where no risks of any kind were checked (the "no identified risk" group), case-report forms with many blanks are routinely accepted so long as at least one risk was checked "yes." Thus, for example, it is not known whether women categorized as drug users were also exposed to heterosexual risks.

Stricter Standards for Reporting Heterosexual Risks

The stricter standards for reporting heterosexual risks could explain certain patterns in the data, such as the relatively high percentage of women (8 percent) categorized as "no identified risk" as compared, for example, to white males (fewer than 2 percent of whom have been categorized as "no identified risk").

CDC has particularly strict standards for reporting heterosexual risks—at least when it comes to AIDS. For example, multiple heterosexual partners are accepted as a form of heterosexual risk for hepatitis B cases, but having had multiple partners does not constitute a reportable risk for AIDS patients.[29] Specifically, heterosexual risks are reported on CDC's standard AIDS case-report form only if one or more of the following AIDS-risk categories apply:

- The patient knows that his or her "index partner" also has AIDS or HIV—a fact that is supposed to be "documented" or confirmed by the local health department before reporting it;
- the patient knows that the heterosexual "index partner" is a member of another risk group—for example, her male partner is bisexual or an opposite-sex partner is an IV-drug abuser;[30]
- the patient (or the patient's sex partner) was born in a foreign country where AIDS cases have been equally divided between males and females.

[28] This is in part because early case-report forms did not include separate items for various heterosexual risks—the health worker was supposed to "fill in" information on heterosexual risks—and in part because even today persons filling out the newer forms have skipped such items. Such persons include nurses, physicians, other hospital workers, and health department staffers. The forms may often be filled in simply by checking a hospital chart on which there is a notation that a particular risk existed (for example, homosexual male) rather than by asking the patient to report whether he or she was exposed to each type of risk.

[29] See, for example, W. J. Alexander et al., "Changing Patterns of Groups at High Risk for Hepatitis B in the United States," Morbidity and Mortality Weekly Report, 37:28 (July 22, 1988), p. 431.

[30] A patient's heterosexual contact with a female prostitute is not included on the standard CDC case-report form—except as any other heterosexual contact would be (that is, only if the prostitute in question is either reported by the AIDS patient as being an IV-drug user or is documented to have AIDS or to be infected with HIV).

By contrast, any admitted homosexual or IV-drug-abuse behavior occurring after 1977 and before AIDS diagnosis is reported as a risk behavior on the CDC form.[31] These differential definitions are based in part on the notion that some persons with AIDS who have engaged in homosexual behavior or IV-drug abuse are reluctant to admit these facts to the health professionals who fill out the CDC forms—and it is possible that misclassification of such persons has occurred on a continuing basis despite the differential standards. However, there is also reason to believe that misclassification in the other direction has also occurred—and that the number of heterosexuals with AIDS may be greater than suggested by the often quoted 4 percent of the total caseload.

The majority of the "no identified risk" cases are found among women with AIDS and/or Blacks and Hispanics.[32] This is significant because it is increasingly recognized that heterosexual transmission cases have been linked to IV-drug-using sex partners and that such cases have occurred primarily among women and inner-city minority groups. Because "no identified risk" cases are concentrated among women and minorities, AIDS patients with heterosexual risks that cannot be confirmed—for example, heterosexuals who over the years had multiple sex partners whose drug-use behaviors were unknown—may represent a substantial number of all cases in which no risk was ever identified—not even after follow-up.[33]

Additionally, patients who were exposed to AIDS both heterosexually and through drug abuse may be erroneously reported to CDC as only having engaged in, for example, drug-risk behaviors (with no report of a heterosexual AIDS risk).

[31] According to a CDC staff member, even a report of an isolated instance of IV drug abuse by a health professional or "medic" who maintained that a sterile needle had been used would be counted as a risk behavior. The reason given was that CDC would have no way of confirming that the needle used was in fact sterile.

[32] The NIR category presently constitutes 3 percent of all AIDS cases. CDC devotes special efforts to reclassifying cases with "no identified risk." CDC has developed a special protocol for follow-up in these cases and has encouraged its use by state health departments. While "no identified risk" cases initially number 5 percent of all reported cases, follow-up efforts have resulted in the reduction of this number to 3 percent—and CDC hopes to eventually reduce it to 2.5 percent or even 2 percent.

[33] As is well known, many reclassified cases represent patients who, when re-approached by public health workers in follow-up interviews, admit the fact of homosexual behavior or IV-drug abuse; undercounting of these cases is thereby reduced. Many of those who are not reclassified report a history of other sexually transmitted diseases.

Nontabulation of Heterosexual Risks: The Hierarchical Rule

When multiple risks are recorded on the case-report form and reported to CDC, the heterosexual risk is essentially discounted. That is, in CDC's summary tabulations, a hierarchical rule has been applied: Homosexual behavior and IV drug abuse rank high and are always tabulated.[34] But heterosexual risks rank lower in the CDC's hierarchy and are not tabulated if homosexual or drug risks were also reported. These multiple-risk cases (heterosexual and other risks reported) represent 2.5 percent of all reported AIDS cases, a large percentage in comparison to the 4 percent of AIDS cases that CDC has categorized as exposed to heterosexual risks (only).[35]

Limitations of Heterosexual Information on CDC's Public Use Data Set

The limited amount of information about heterosexual risks on the public use data set provided by CDC tends to compound the situation discussed above by effectively curtailing tabulations and trend analyses on heterosexuals with AIDS that can be produced by other investigators. This in turn can hinder public awareness of trends among certain groups of heterosexuals with AIDS.

Only summary fields for risk-group membership have been included on CDC's public use tape for AIDS case-reports. In the key field on the CDC public use data set, the hierarchical rule has been applied to classification of multiple-risk cases so that, for example, persons reporting both heterosexual risk and IV-drug use have been coded only as IV-drug users. As a result, CDC's routine tabulation practices (previously described) carry over to risk-group tables produced by others.

An additional difficulty with CDC's public use data set is that many of the cases that were tabulated as heterosexual risks (after the hierarchical rule had been applied) are "lumped" together, without any indication of the specific heterosexual risk that was reported. For example, in using the CDC public use data set, it has not been possible to distinguish a case in which a woman with AIDS had a sex partner who was an IV-drug user from one involving a woman whose sex partner was a bisexual male.

Until mid-1988, it was not possible for investigators to separate out definitively those AIDS cases that had been "presumptively" categorized

[34] If both homosexual and IV-drug-abuse risks are reported, the case is tabulated in a special category.

[35] By January 1989, the size of this multiple-risk group had risen from 2.5 percent to 4.1 percent. This trend is largely attributable to the increased number of cases reporting both drug-abuse and heterosexual risks.

as heterosexual—that is, cases designated as heterosexual-risk cases merely on the basis of birth in a foreign country in which the epidemic was known to follow a heterosexual pattern. These presumptively heterosexual cases were mixed together with other cases in which there had been an acceptable report of heterosexual contact with a partner at increased risk for AIDS. And, although this distinction was added to the data set in mid-1988, it was still not possible for investigators outside CDC to separately examine other segments of the heterosexual-contact group (such as cases of reported heterosexual contact with an IV-drug user, with a bisexual male, or with another person documented as HIV positive or diagnosed with AIDS). Such distinctions may, in the coming months or years, be important in examining potential spread of the disease to various segments of the heterosexual population.

Newly Recognized Trends Within the Heterosexual Group

Recent analyses conducted by CDC show important trends within the heterosexual category. (See table 4.5.) Most notably, the percent of cases attributed to heterosexual contact with an IV-drug-using partner or other person at increased risk rose from about 1 percent in 1982-1983 to nearly 4 percent of new cases in 1987-1988.[36] Such trends were masked, however, when these heterosexual-contact cases were combined with the foreign-born presumptively-defined heterosexual cases (which, as a percentage of new cases, declined considerably over this period). Early in the epidemic, U.S. residents born in countries where heterosexual transmission of HIV is common constituted a much larger portion of heterosexual cases than they do today.

[36]In an earlier published article (Morgan and Curran, 1986), CDC analyses indicated an increase from 1 percent to 2 percent by 1986.

Table 4.5: Trends in Heterosexual-Risk Cases: Percentage (And Number) of AIDS Cases Categorized by CDC as Having Been Exposed to Specific Kinds of Heterosexual Risks

	Year of diagnosis					
Heterosexual risk	**1982-83**	**1983-84**	**1984-85**	**1985-86**	**1986-87**	**1987-88**
Heterosexual contact with IV-drug user	0.9% (19)	0.9% (40)	1.2% (106)	1.7% (219)	1.9% (347)	2.6% (371)
Heterosexual contact with bisexual man, with hemophiliac, or with transfusion recipients	0.1 (4)	0.2 (10)	0.3 (27)	0.4 (55)	0.5 (77)	0.6 (79)
Heterosexual contact with other HIV-positive person	0.0 (0)	0.0 (2)	0.0 (2)	0.2 (27)	0.3 (57)	0.4 (61)
Total	**1.0 (23)**	**1.1 (52)**	**1.5 (135)**	**2.3 (301)**	**2.7 (481)**	**3.6 (511)**
Combining all above categories, 1503 heterosexual-contact cases were diagnosed and reported from June 1982 to June 1988; these cases represent 2.5 percent of the 61,140 "old definition" cases diagnosed during those years.						
Foreign birth: country with equal numbers of male and female cases	4.2 (90)	2.5 (113)	1.8 (150)	1.4 (178)	1.1 (201)	1.0 (152)
Cumulative across = 884; divided by 61,140 = 1.4%; 2.5% + 1.4% = 3.9%						

Note: Table adapted from CDC's unpublished analyses of the 1987 definition change. Only cases qualifying for CDC's "old" AIDS case definition (pre) are included here, but these are analyzed for diagnoses and reports through June 1988. The limitation to "old definition" cases is important because heterosexual-risk and drug-use-risk cases are more numerous among "new definition" cases. A recent report by the U.S. Public Health Service (1988a) indicates that because of the definition change, it is not possible to conclude whether there has been a real increase in heterosexual cases. This table, adapted from CDC's unpublished analyses, isolates the "old definition" cases.

Data are categorized by diagnosis year—July 1 of previous year to June 30 of next year. The table omits data from the earliest year (July 1981-June 1982) because of small numbers.

Only when trends in the various categories are separately considered, as in table 4.5, is it possible to see the expansion of AIDS cases in the heterosexual population. The lumping together of all heterosexual cases may have conveyed an erroneous impression of stability.[37] Given that such mistaken impressions have occurred, there is clearly a need for greater detail on risk-group information in the public use data set.

[37]One example of such an erroneous impression is included in the recent report of the National Center for Health Services Research and Health Care Technology of the Public Health Service; citing the continuing 4 percent figure for cumulative heterosexual cases given in CDC's weekly surveillance report, this report points to the stability in heterosexual cases.

Quality of Time-To-AIDS Data

The interval between infection with HIV and the development of a clinical diagnosis of AIDS (known as the incubation period or time-to-AIDS) is generally thought to be long and highly variable among individuals. Precise determination of these values has been complicated by the relative newness of the AIDS epidemic and several measurement problems. The result of these problems is the underestimation of the true incubation period.

In particular, since AIDS was not discovered until 1981, there has been a limit on the maximum follow-up period for investigating time-to-AIDS. Early studies were likely to underestimate the true median or mean incubation period because many HIV-infected individuals had not yet progressed to AIDS. In technical terms, the observed distributions had been censored. That is, a censored distribution would be missing observations that would appear in the right tail of the distribution as follow-up time is increased. In this case, the distribution is called "right censored."

A second factor that can bias time-to-AIDS data concerns the measurement of initial HIV infection. With the exception of individuals who became infected as the result of an isolated blood transfusion involving HIV-contaminated blood or blood products, it is exceptionally difficult to determine when an individual was initially infected. Some studies based their estimates of time-to-AIDS on subjects for whom the specific date of infection was unknown; in many instances, the infection may have occurred at any point across a wide time interval. For example, the majority of participants in a West German study were HIV positive at the start of the study. For this factor, the bias in estimating the mean or median incubation period results from censoring the left-hand side of the time-to-AIDS data.

In addition to these biases, the available empirical assessments of time-to-AIDS have involved small samples of individuals. Lui et al. (1986) analyzed 83 individuals who had contracted HIV through blood transfusions and subsequently developed AIDS. The imprecision of their estimate—due in part to the small size of the sample—is revealed in the fact that the 90 percent confidence interval around a mean incubation of 4.5 years ranged from 2.6 to 14.2 years. This study used mathematical models to adjust for right censoring of the data, however. Another study, Hessol et al. (1987), estimated the fraction of infected persons that were diagnosed as AIDS cases over time, based on 155 participants. Specifically, Hessol et al. estimated that only 15 percent would develop AIDS in the first 5 years, 24 percent by the end of the sixth year, and 31 percent by the end of the seventh year (95 percent confidence interval, 22 to 40 percent).

In general, more recent studies have revealed long incubation periods. For example, Bacchetti and Moss (1989) report a median incubation period of 9.8 years.

As seen in table 4.6, only a few forecasting models have used values for the time-to-AIDS parameter that would yield unrealistically low estimates of the cumulative number of AIDS cases. Instead, most models contain median values that are consistent with current evidence or assume distributions of the progression of cases that encompass plausible time intervals. (See the lower half of table 4.6.)

Table 4.6: Alternative Values for Time-To-AIDS Calculations in Existing Models.

	Time-to-AIDS, in years											
Study categories	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Medians of theoretical distributions												
Brookmeyer & Gail, 1986			X	X	X	X						
Brookmeyer & Gail, 1988				X	X	X	X	X				
Brookmeyer & Damiano								X				
Harris					X							
Artzrouni				X				X				X
Studies using rates of conversion or probabilities of progessing to AIDS diagnosis												
Cowell & Hoskins[a]	X	X	X	X	X	X	X	X	X	X	X	X
Dahlman et al.[b]	X	X	X	X	X	X	X	X	X	X	X	X
Cardell & Kanouse[c]	X	X	X	X	X	X	X	X	X	X	X	X
Plumley[a]	X	X	X	X	X	X	X	X	X	X	X	X

[a]Cowell and Hoskins, as well as Plumley, used conversion rates up through 20 years. Median for both is about 8 or 9 years.

[b]Dalhman et al. used conversion rates up through 17+ years. Median is between 10 and 12 years.

[c]The Cardell and Kanouse model used probabilities of progressing to AIDS diagnosis, indicated for each successive year; their model calculated this probability for over 15 years, after which the probability dwindled to near zero.

Overall Assessment of the Forecasts and Specification of a More Realistic Range

As discussed in chapter 2 of this report, the 13 existing national forecasts of cumulative AIDS cases for 1991 vary considerably—with best estimates going from about 120,000 to 400,000 and with the full spectrum of possible predictions encompassing an even broader range. These forecasting models differ substantially in terms of their comprehensiveness, the soundness of their empirical base, the plausibility of their assumptions, and the extent to which they have been adjusted for biases in the data that are used. Using these criteria, we examined each forecast and made approximate adjustments to correct for data biases. As a result, we estimate that

- the currently reported range of forecasts for 1991—including best-estimate forecasts of 120,000 to 400,000 cases and lower and upper-bound predictions that go from about 85,000 to 750,000 cases—can be narrowed to a more realistic range;
- the most realistic forecasts—including upper and lower-bound predictions—range from about 300,000 to 480,000 cumulative cases through 1991.

As discussed in chapter 3 and summarized in table 3.1 (on p. 24), the 13 AIDS forecasting models are based on four major forecasting methods and can be described as follows:

- extrapolation through 1991 of existing trends in AIDS cases, based on the national surveillance data (5 models);
- back-calculation—using the national surveillance data and time-to-AIDS data to estimate existing trends in HIV infection and to predict the number of already infected persons expected to develop AIDS by year end 1991 (2 models);
- macro-level simulation—using the national surveillance data, time-to-AIDS data, and major assumptions about the nature of the epidemic to model existing and future trends in HIV infections and conversions to AIDS by 1991 (4 models);
- micro-level computer simulation—using the national surveillance data and time-to-AIDS data as well as various assumptions concerning individual risk behaviors and transmission probabilities to model the epidemic's development through 1991 (2 models).

These forecasting methods and the models subsumed under them are assessed below in regard to comprehensiveness, soundness of the empirical base, reasonableness of assumptions, and adjustments made to correct for data biases.

Comprehensiveness of Models

The extrapolation-based models are the least comprehensive; that is, they do not devote explicit treatment to epidemic components and population subgroups. Back-calculation and macro-simulation models represent an intermediate level of coverage. The pure back-calculation method addresses current and past levels of HIV infection and the progression of the disease (that is, time-to-AIDS). Macro-simulation models augment these parameters by modeling future trends in HIV infection levels for separate risk groups. Micro-simulation forecasters are the most comprehensive, taking into consideration several components of the epidemic and various population subgroups.

In order to provide a systematic assessment of the comprehensiveness of AIDS forecasting models and to obtain a framework for applying the other criteria, we identified six specific aspects of the epidemic that were measured by forecasters. The six major components forecasters used to measure the epidemic are as follows:

1. the prevalence and frequency of individual risk behaviors, which would include the size of risk groups as well as future trends or possible changes in risk behaviors;

2. the efficiency of HIV-transmission for various risk behaviors—and, conceivably, possible changes in those efficiencies (as might occur, for example, if a vaccine were developed);

3. the mixing of uninfected and infected persons—for example, within and across sexual-preference and drug-using groups or across geographic areas and, conceivably, as determined by the numbers of partners with whom uninfected and infected persons engage in risk behaviors;[1]

4. past and current HIV infection levels—logically, an outcome of the three foregoing components;

5. future trends in HIV infection levels (resulting from the combined effects of the four previous components); and finally,

6. the process of disease development among persons with the HIV infection—and, conceivably, changes in this process (as might result, for example, from future medical treatments).

[1]The models reviewed here—that is, those on which existing (U.S.) national forecasts are based—did not, however, take into account numbers of partners.

In addition, inclusion of a variety of population subgroups within the models was deemed an important criterion for a comprehensive model. As described in chapter 3, some forecasters considered the epidemic components separately for various subgroups, including (1) HIV-transmission risk groups (principally, IV-drug users, homosexual males, or nondrug-using heterosexuals) and (2) demographic subgroups such as sex, age, race, and geographic area of residence.

As summarized in table 5.1, the major types of AIDS forecasting models differ considerably in how comprehensively they cover (1) six components of the epidemic and (2) various risk groups and demographic subgroups of the population. Clearly, the micro-simulation models are the most comprehensive, measuring all six components as well as risk groups and demographic subgroups.

Table 5.1: Comprehensiveness of AIDS Forecasting Models

	Six components of the epidemic measured by forecasters[a]						Subgroups measured by forecasters[a]	
Forecasting method	1. Prevalence and frequency of risk behaviors	2. Efficiency of HIV transmission for risk behaviors	3. Mixing of persons (risk behaviors)	4. Past, current HIV infection levels	5. Disease development	6. Future trends in HIV infection levels	Risk groups	Race, age, geographics
Extrapolation	-	-	-	-	-	-	-	-
Back calculation	-	-	-	X	X	-	-	-[c]
Macro-level simulation	-	-	-	X	X	X[b]	X	-
Micro-level simulation	X[b]	X	X[b]	X	X	X[b]	X	X[d]

[a]An "X" indicates that the models using this method explicitly treat the component or subgroup.

[b]Change is also modeled as part of the forecast.

[c]Brookmeyer and Damiano present, in addition to their total population forecast, separate back calculation forecasts for various risk groups; however, the risk group forecasts were obtained separately from the total population forecast and are not a component of it.

[d]Plumley examined sex and race separately, whereas Kanouse Cardell examined geographic location and age group.

Comprehensiveness and Empirical Basis

Using the six measured components of the epidemic as a framework, table 5.2 summarizes the empirical basis of the various types of forecasting models. Extrapolation models (the least comprehensive) are rated "high" in terms of their empirical basis because they depend directly upon the caseload trends represented by the national surveillance data (which are reviewed in chapter 4 of this report). Back-calculation models were rated "medium/high" in terms of having a sound empirical base, macro-level simulations were rated "medium/low," and those at the micro level "low"; these overall ratings were based on empirical basis ratings for the individual components of the models.

Table 5.2: Comprehensiveness of AIDS Forecasting Models: Empirical Basis

Model/forecast	Six components of the epidemic measured by forecasters: 1. Prevalence and frequency of risk behaviors	2. Efficiency of HIV transmission for risk behaviors	3. Mixing of persons (risk behaviors)	4. Past, current HIV infection levels	5. Disease development	6. Future trends in HIV infection levels	Overall empirical basis rating
Extrapolation							High [a]
Back calculation				Medium	High		Medium/high
Macro-level simulation				Low/medium	High	Low	Medium/low
Micro-level simulation	Low	Low	Low	Medium	High	Low	Low

[a]Extrapolation models, which do not address any of the six individual components of the epidemic, are based directly on global trends in surveillance data.

Individual-Level Behaviors and Events (Components 1 Through 3)

Only the micro-simulation models (which were deemed the most comprehensive) included the individual-level components of HIV spread. However, as table 5.2 indicates, there is little empirical basis for setting parameters for these components at the present time. Currently, there are no national data on the prevalence and frequency of specific behaviors such as homosexual and heterosexual acts or sharing of needles in IV-drug use. Little information is available on HIV transmission probabilities for specific risk behaviors, and perhaps even less is known about a host of "mixing" factors or barriers to interpersonal interaction with respect to HIV risk behaviors.

As described in chapter 3 of this report, micro-level forecasters have, to date, relied on three strategies to estimate parameter values for these components:

- explicit assumptions (for example, Plumley's assumption that there is no mixing across racial lines with respect to the various risk behaviors);
- partial data (for example, Kanouse and Cardell's estimate of 1.2 million IV-drug users who share needles, which is based on admittedly flawed estimates of the prevalence of heroin use and essentially no quantitative data on either route of administration or needle-sharing among IV users); and
- data of questionable quality (for example, the estimates of the size of the homosexual and bisexual male populations that are based primarily on the Kinsey study (Kinsey, Pomeroy, and Martin, 1948), which is now

outdated, was not based on probability sampling, and classified persons as homosexual or bisexual based on "orientations" or feelings as well as their actual behaviors).[2]

Because of the uncertainty surrounding these parameter values, micro-level forecasters have used the national surveillance data as a way of adjusting or calibrating the values they initially selected.[3] The empirical basis for components 1 through 3 has therefore been rated "Low."[4]

Past-Current HIV Infection Levels and Disease Development (Components 4 and 5)

With the exception of those models that extrapolate current trends in the national surveillance data, all models forecasting AIDS cases involve estimation of past and current HIV infection levels and depend, in part, on modeling disease development—that is, the incubation period between HIV infection and the development of AIDS among infected persons.

With respect to disease development (component 5), forecasters have based parameters directly upon the empirical time-to-AIDS studies reviewed in chapter 4 of this report; in some cases, forecasters have improved such data via statistical adjustments. Therefore, the empirical basis of this component is rated "High" in table 5.2.

With respect to estimating past and current HIV infection levels (component 4), a variety of approaches have been used with various outcomes. The majority of forecasters who provide such estimates put HIV infection levels as of 1987 at 800,000 to 1,000,000 or higher. Lower infection levels for 1987 are associated with lower numbers of cases forecast for 1991. (For example, Artzrouni's estimate of 449,000 infections in 1987

[2]Recently, data from a 1970 national sex survey has become available (see Fay, Turner, et al.,1989); this study was aimed at updating some of Kinsey et al.'s (1948) results, but from 1970 to 1989 data had been "kept under wraps because of squabbling over methodology and authorship" (Booth, 1989).

[3]In other words, the first step was to choose seemingly plausible initial values, based on strategies 1 through 3 above. The second step was to adjust these values so that the model output would match trends in the national AIDS surveillance data—either globally or within relevant risk groups. For example, Plumley adjusted risk-behavior frequencies separately by race and risk group to match national surveillance trends within these categories.

[4]Some proponents of the micro-model approach believe that because their models are "calibrated" to produce results that match actual trends in the national AIDS surveillance data in recent years, these models are as reliable (at least for the short-range) as the extrapolation models that are more obviously or more directly based on the national surveillance data.

is associated with his forecast of 159,000 cases for 1991.) Most forecasters dealing with this component draw on both national surveillance data and time-to-AIDS data.[5]

For back-calculation models, and for other models using similar methods to estimate HIV levels up to the present time, we have rated the empirical basis as "Medium" (meaning that HIV levels are indirectly estimated based on two empirical data sources).

Macro-simulation models not only have drawn on national surveillance data and time-to AIDS data, they have, in some cases, also made explicit assumptions about the nature of past and current HIV trends—which may or may not be modeled separately for the different "risk groups." For example, as discussed in chapter 3, Artzrouni assumes that the rate of new HIV infection is a decreasing function of the cumulative number of ever-infected individuals;[6] Artzrouni also assumes that "the population is homogeneous with respect to .... infectivity." The combination of these two assumptions has the logical effect of eliminating from his model the possibility of significant expansion of the epidemic into the ("last-hit") heterosexual population. Artzrouni states: "...the vast majority of AIDS cases can still be found among the high risk groups of homosexual/bisexual and IV drug abusers. Until there is more evidence of substantial numbers of cases infected through very different routes, it is felt that a model that would take heterogeneity into account would be fruitless" (p. 12). As a result of this approach, Artzrouni's modeled HIV epidemic shows a very early peak (in 1983).

To cite another example, one macro-simulation forecast (Pascal's upper-bound forecast) is based on a very high number of current infections—1.5 million persons in 1986. Rather than back-calculation, this estimate is the upper bound of the June 1986 "estimate" (1 to 1.5 million

[5]The time-to-AIDS parameter is a crucial ingredient for this key component, as discussed in chapter 3. If the time-to-AIDS is very lengthy for large numbers of infected persons, then the AIDS cases we see at present (that is, those that have come to light so far) represent only a small fraction of the total number of existing infections—and the total number of projected current infections is therefore large in comparison to the number of known cases.

[6]Artzrouni maintains this assumption is consistent with such information as the following: reports that HIV infection levels have held steady among Army recruits and first-time blood donors, reports of high levels of infection having already occurred in key risk groups (which he combines with the notion of saturation), and the decelerating growth rate in the numbers of new AIDS cases.

infected) made by CDC at the Coolfont conference.[7] However, because there was little empirical basis for this CDC figure, we have classified Pascal's parameter here as an assumption rather than an empirically based estimate. (See the discussion below concerning the plausibility of assumptions.)

Thus, for the subset of macro-simulations that have relied heavily upon assumptions in estimating earlier and current HIV infection levels, we have rated the empirical basis as "Low," whereas others were rated "Medium." Hence, the overall "Low/Medium" rating for this category.

Micro-simulation models base past and current HIV infection levels on a variety of sources, but principally on combining the results of modeling individual-level components (which include adjustments to match trends in national surveillance data) with the disease-development parameter (time-to-AIDS). Kanouse and Cardell supplement this approach with the limited information that exists on HIV prevalence for specialized populations in local areas at specific points in time. Therefore, for micro-simulations, we have rated the empirical basis of their parameter for previous HIV trends as "Medium."

Future HIV Infection Trends (Component 6)

Only the macro-level and micro-level simulation forecasts model future HIV infection trends.[8]

For macro-simulation forecasts, this component is based heavily on explicit assumptions and sensitivity analyses in which assumptions are varied. For example, Cowell and Hoskins assume, first, that HIV infection will not spread significantly outside the current high-risk groups. And, second, they assume that within such groups, HIV is spreading according to an S curve and—for their "best estimate"—that the spread will stop when 60 percent of homosexuals and IV-drug users have been infected (an outcome that is predicted for 1997, whereas under 30 percent of these groups were assumed infected as of 1987). This assumption is varied in Cowell and Hoskins' sensitivity analysis: For their lower-bound estimate, they assume no new infections; while for their upper bound

[7]See Institute of Medicine, National Academy of Sciences, Confronting AIDS (Washington, D.C.: National Academy Press, 1986) and U.S. Public Health Service, "Coolfont Report: a PHS Plan for Prevention and Control of AIDS and the AIDS Virus," Public Health Reports, 101 (July-August 1986), pp. 341-348.

[8]Exceptions are the Harris forecast and the Brookmeyer and Damiano upper-bound forecast, which extrapolate HIV infection trends either globally (Harris) or within risk groups (Brookmeyer and Damiano).

estimate, they assume that infection will spread to 100 percent of the high risk groups. Because this component is so heavily based on assumptions by macro-level simulation modelers, we have rated its empirical base as "Low."

For the micro-simulation modelers, future HIV infections were determined by the other five components. Because three of these five determining components are rated "Low" on empirical basis, the sixth or outcome component is also rated "Low."

Plausibility of Assumptions

Assumptions About Individual-Level Components of the Epidemic (Components 1 Through 3)

Modeled only by the micro-simulation forecasters, components 1 through 3 rely heavily on assumptions. However, because so little is currently known about these aspects of the epidemic, we could not judge the plausibility of the specific assumptions that were made.

Assumptions About Past-Current HIV Infection Levels and Disease Development (Components 4 and 5)

For most forecasters, components 4 and 5 are largely or totally empirically based. Two exceptions are Pascal and Artzrouni. With respect to component 4 (past-current HIV infections levels), Artzrouni's model produced one of the lowest estimates of HIV infection (449,000 in 1987), whereas Pascal's upper bound was based in part on an estimate of 1.5 million infected in 1986.

Pascal's 1.5 million infected—from CDC/Coolfont[9] —was derived from the very limited information available in mid-1986 on the likely size of the various risk groups and on HIV prevalence within those groups. The CDC estimate of HIV infections has since been revised; acknowledging that the number of infected Americans in 1986 was probably less than 1 million, CDC estimated that 1 to 1.5 million were infected as of 1988. The more recent (1988) estimate is based on numerous local studies of special population groups, as well as on seroprevalence testing of military

[9]See Institute of Medicine, National Academy of Sciences, Confronting AIDS (Washington, D.C.: National Academy Press, 1986) and U.S. Public Health Service, "Coolfont Report: a PHS Plan for Prevention and Control of AIDS and the AIDS Virus," Public Health Reports, 101 (July-August 1986), pp. 341-348.

recruits and blood donors, and even on preliminary results from the first studies testing hospital patients.[10]

While these two estimates are the same (a high value of 1.5 million infected), the crucial point is that the time difference between the two estimation points (2 years), when combined with the fact of the continuing and very likely expanding epidemic, means that at the time of Pascal's forecast 1.5 million was a considerable overestimate. Pinpointing Pascal's HIV estimate in time is important because he combined this estimate with a time-to-AIDS factor in order to produce the forecast of cases for 1991.

Further, in our opinion, the assumption of 1.5 million infected as of 1986 is less plausible in light of the short time-to-AIDS (component 5) specified in Pascal's report—50 percent of infected persons would be diagnosed as AIDS cases within 5 years (based on Johnstone, 1986).[11] Thus, in light of current knowledge, the assumption of 1.5 million infected as of 1986 is not plausible, especially given the relatively short time-to-AIDS with which it was combined.

Assumptions About Future Infection Levels (Component 6)

Two questionable assumptions are made by some forecasters with respect to future infection levels: (1) no new infections and (2) containment of new infections within the current high risk groups (homosexual males and IV-drug users).

These assumptions are made primarily in models employing back-calculation procedures (no new infections) or macro-level simulators (containment). Micro-level simulations base estimates of future infection levels on the outcome of contributing components, although these are not firmly grounded in empirical evidence.

No New Infections

The core assumption of the back-calculation approach—when it is not supplemented by other approaches—is that no new infections will occur. Other forecasters have used this assumption to define a lower

[10] See Centers for Disease Control, U.S. Public Health Service, Morbidity and Mortality Weekly Report, 36:S-6 (December 1987).

[11] As explained in Chapter 3, the shorter the time to AIDS, the closer one would expect the number of existing HIV infections to be to the number of already existing AIDS cases: thus, a relatively short time-to-AIDS would logically not be coupled with such a large number of as yet undiagnosed HIV infections.

bound (Cowell and Hoskins). We believe an assumption of no new infections is less plausible than an assumption that some level of new infections will occur, and that the best-estimate forecasts and lower bounds based on this assumption are unreasonably low.

The reason for our belief is that an assumption of no new infections carries other implicit assumptions concerning trends in risk behaviors (that these cease as of the date the forecast is made) or transmission efficiencies (that these are immediately reduced to zero by, for example, a vaccine) or mixing behaviors (that uninfected individuals no longer come in contact with individuals who are infected)—or some combination of the three. These assumptions of extreme, immediate change are not supported by available evidence. And, especially for 5-year forecasts (1986 data used in forecasts for 1991), the number of future cases that could be expected to result from new infections would not be trivial.

Containment of New Infections Within High-Risk Groups

Some forecasters assume that either there will be no new infections in the non-drug-using heterosexual population or no expansion of the percentage of cases attributable to heterosexual transmission. We believe these assumptions are less plausible than assuming that infections may, in fact, spread beyond the current high-risk groups. Our judgment is based on several factors.

First, as discussed in chapter 4, several issues are involved in the existing categorization of the national surveillance data into the various risk groups. These issues or problems—including lack of information on many case-report forms regarding the multiple risks to which AIDS patients were exposed, hierarchical classification of those cases where multiple risks were reported, and differential levels of evidence required for the reporting of various risks—may combine to produce an understatement of the numbers of AIDS cases involving heterosexual exposure. These problems are compounded by the limited data on heterosexual risks and on multiple risks that have been provided on the CDC public use data diskettes; these data limitations made it difficult for forecasters to track trends within various types of heterosexual exposure groups or to study multiple-exposure cases involving heterosexual risks.

Second, analyses conducted by the CDC indicate that there has been an increase in the proportion of cases involving heterosexual risks. These analyses—aimed at identifying changes in reported cases due to recent changes in CDC's case definition—separate out AIDS cases classified as heterosexual because of birth in certain foreign countries known to have experienced large numbers of cases resulting from heterosexual transmission. These presumptively heterosexual cases represented a substantial proportion of the U.S. total early in the epidemic but today represent only about 1 percent of new cases. By contrast, there has been an increase from 1 to nearly 4 percent in other cases classified as heterosexual—chiefly because the patient's heterosexual partner is known to be an IV-drug user.

As of July 1988, the large majority (77 percent) of the 1,100 cumulative cases in this category (heterosexual partner of an IV-drug user) were women—mostly Black and Hispanic women; the men with AIDS in this category were also drawn, for the most part, from minority groups. This reflects the heavy overrepresentation of minorities among women and children with AIDS: 70 percent of the more than 5,000 women with AIDS are Black or Hispanic, as are 75 percent of the more than 1,000 children with AIDS. As a result, we believe that it is not plausible to—directly or indirectly—"assume away" all possibility of heterosexual transmission of the virus—especially in minority communities.[12]

Forecasters' Adjustments For Problems in National Surveillance Data

As shown in table 5.3, with respect to "delayed-count" problems, most forecasters have introduced adjustments to deal with the problem of lags in reporting diagnosed cases to CDC, and one model has also adjusted for late diagnosis.

[12] At least one forecaster who assumed no heterosexual transmission in future years noted, in a personal communication to us, that some new information had come out since the time his forecast was made which indicated that the heterosexual group may play a greater role in the epidemic than was previously thought. Yet he believes the assumption was "not crippling" insofar as making a forecast for 1991 and that it would be more important in making a longer-term forecast (for example, a forecast for the year 2000).

Table 5.3: Biases in National Surveillance Data Taken Into Account by National Forecasters

	Delayed count biases			
Forecasts	Cases diagnosed late	Cases reported late	Illnesses not in AIDS definition until 9/87	Illnesses still not in AIDS definition
Extrapolation				
1. Fuhrer. 1988		X		
2. CDC, 1986		X		
CDC, 1988		X	X	
3. Los Alamos, 1988 (cubic)		X		
4. Hellinger, 1988		X	X	
5. HCFA, 1987		X		
Back calculation				
6. Brookmeyer & Gail, 1986		X		
Brookmeyer & Gail. 1988		X		
Brookmeyer & Damiano, 1988		X		
7. Harris, 1987		X		
Macro-level simulation				
8. Artzrouni, 1988		X		
9. Dahlman et al., 1988		[b]		
10. Cowell and Hoskins, 1987		[b]		
11. Pascal, 1987		X		
Micro-level simulation				
12. Plumley. 1988		X		
13. Cardell and Kanouse. 1988	X	X	X	

[a]Although CDC did not make a numerical adjustment for the fact that presumptive diagnoses with HIV tests were not counted before September 1987, they did allow into their analyses such cases that were diagnosed before July 1987 but reported after September 1987.

[b]Although a formal numerical adjustment was apparently not made, these forecasters implicitly took this factor into account.

Undercount biases				Overcount biases	
Cases never diagnosed	Presumptive diagnoses with HIV tests not counted until 9/87	Presumptive diagnoses without HIV tests still not counted	Cases never reported	False positive diagnoses	Doubly counted cases
	(X)[a]		X		
			X		
	X		X		
			X		

With respect to undercount and overcount problems, four forecasts have included adjustments to "correct for" diagnosed cases that were never reported to public health authorities. Three have also adjusted for illnesses not included in the case-count prior to the September 1987 definition change. In a couple of instances, forecasters corrected for cases not counted in the national surveillance data prior to September 1987 because physicians had not conducted the tests that were required by CDC to confirm specific illnesses.

The adequacy of these adjustments has not been assessed. Indeed, without further study of the problems and their magnitude, it would be difficult to criticize an adjustment with confidence or to evaluate its adequacy. However, many problems have not been adjusted for at all in one, several, or all models. As discussed in chapter 4, undercounting problems are sizable.

Method of Specifying a More Realistic Range

We believe a more realistic range of forecasts can be specified by a two-step process: (1) rating of existing forecasts in terms of the plausibility of the assumptions they contain and (2) adjusting some existing forecasts to more realistic levels based on what information is available concerning the likely biases in the national surveillance data. In particular, using estimates of the magnitude of these problems from existing (often local) empirical studies of the national surveillance data (see chapter 4 of this report, especially table 4.4 basis-1 calculations), we adjusted each reported forecast to take into account the known problems that had not been considered by that forecaster. Our adjustment for each problem was based on a rough estimate of what percent of the "true total" (that is, what percent of all cases of fatal HIV-related illnesses) had not been counted because of that specific problem. We then summed our estimates of the sizes of the biases to be used in our adjustment for each forecast. (One data problem was not included in these adjustments because of a lack of any empirical data on its size—that is, the percentage of AIDS cases never diagnosed, not even at death.)

First, based on forecasters' assumptions and parameter values regarding specific components of the epidemic, we examined the best estimate for existing forecasts and the upper and lower bounds that were reported. Estimates for forecasts based on the assumption of no new infections or on CDC's (since revised) upper-bound "estimate" of 1.5 million HIV infections in 1986 (Pascal) were judged unrealistic. Further, we questioned the realism of forecasts (or range bounds) based on the (direct or indirect) assumption of no further spread in the heterosexual population (either no new infections or no expansion beyond the current percent of cases). Only those forecasts that contained plausible assumptions were included in our determination of a more realistic range for 1991.

Next, based on our preliminary assessment of the quality of the national surveillance data and on the adjustments that the various forecasters did (or did not) make to "correct for" the undercount, we indicated, where possible, the extent to which forecasts might be shifted upward. As stated above, only those forecasts that contained unreasonable assumptions were excluded from our determination of a more realistic range for 1991.

Our adjustments were tailored for each forecast. Specifically, only when a forecast (such as CDC's 1986 forecast for 1991 or several others in table 5.3) included no adjustments for undercount/overcount problems did we adjust for all such problems that had been estimated on an empirical basis (basis 1 calculations in table 4.4).[13] In such instances, we recognized that the forecast was based on a likely count of only about 2/3 of the total number of cases of fatal HIV-related illness—in other words, about 67 out of 100 relevant cases had been captured in the data underlying the forecast. Thus, in order to adequately represent the universe of relevant cases, the cases that were captured should be multiplied by about 100/67 or 3/2. That is, 67 multiplied by 3/2 (or 1.5) yields about 100 cases. We followed this procedure in making adjustments to forecasts that had not already been adjusted for undercount/overcount problems.[14]

By contrast, when a forecast had already been adjusted for two undercount problems (for example, HCFA had adjusted for our problems 5 and 7), we recalculated our estimate of the net undercount, again using table 4.4 basis-1 calculations but omitting those problems that had already been taken into account. Not counting problems 5 and 7, we estimated the forecasts were based on an adjusted count of 84 percent of the total relevant cases (that is, 84/100 cases), and we therefore multiplied each forecast by 100/84 to produce a fully adjusted forecast.

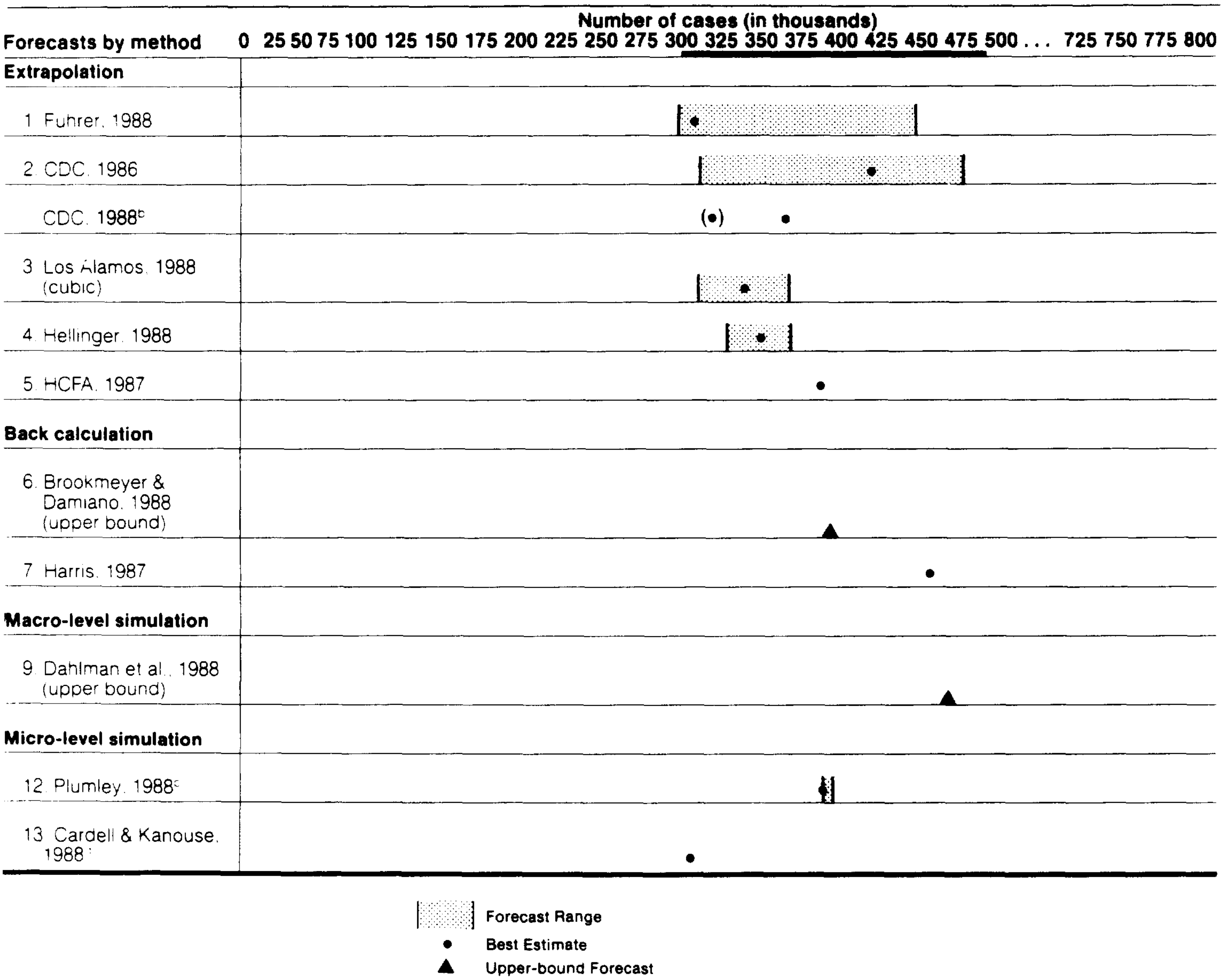
[13]Such forecasts typically did correct for at least one "delayed count" problem—lags in the medical community's reporting of diagnosed cases to public health authorities.

[14]For purposes of comparison, using the recently released New York City report and following the logic described above, if only about 50 percent of all New York City's cases of serious HIV-related illness are counted in the surveillance system (see note on p. 55 of this report), then in our judgement a 2-to-1 inflation factor would be needed in forecasts for that city.

Figure 5.1 lists the forecasts and upper and lower bounds we categorized as most realistic and shows the adjusted levels of these forecasts, once our estimates of the appropriate upward adjustments had been applied to correct for the net effect of undercounting and overcounting biases in the national surveillance data. Based on the adjusted levels of the more plausible forecasts—including their upper and lower bounds—a "more realistic range" for 1991 would be about 300,000 to 480,000 cumulative cases by the end of that year.[15] This range is based on our recognition that forecasting necessarily involves an element of uncertainty and that considerable uncertainty about the AIDS epidemic remains—even after taking into account what information is available and making adjustments for data biases.

[15]As previously noted, our upward adjustments did not take account of AIDS cases that have never been diagnosed; these uncounted cases were omitted from our adjustments because no existing empirical study has estimated their numbers (although CDC says such a study is being planned). If the expert-opinion estimate of 10 percent undercount due to this problem were added to our calculations for purposes of extending the upper bound of our range, the upper bound would be about 525,000 cases by 1991.

Figure 5.1: A More Realistic Range: Adjustment of Selected National Forecasts of Cumulative Cases Through 1991, by Forecasting Method[a]



[a]We adjusted selected forecasts based on estimated sizes of undercount and overcount problems given in table 4.4 (using the calculations made on basis-1, empirical studies only), taking into account which problems each forecast had and had not already taken into account. Most forecasts were based on surveillance data for AIDS cases diagnosed before the September 1987 definition change

(continued)

[b]CDC's 1988 forecast allowed late reports of cases that did not meet the pre-September 1987 diagnostic requirements. The primary adjustment shown above assumes that this did not constitute an adjustment for problem 5 in table 4.4. The alternate adjustment (shown in parentheses above) assumes that problem 5 had been adjusted for in CDC's 1988 forecast.

[c]Plumley told us that, after reviewing a draft of this report, he made adjustments to input data for his micro-simulation model; rerunning the model, he came out with a number not quite as large as we had. Plumley said his readjusted forecast came out 40 percent higher (rather than 50 percent higher) than his initial forecast; he believed the reason was that if more cases had occurred in the early years, the high-risk groups would saturate more quickly.

[d]Cardell told us he had also produced an upper-bound forecast of 340,000 cases for 1991 based on an upward adjustment that would account for virtually all undercount factors. This figure had not been released by Rand, however.

Conclusions and Recommendations

The thirteen existing national forecasts of cumulative AIDS cases by the end of 1991 include best estimates ranging from about 120,000 to 400,000 cases; when lower and upper bounds for the forecasts are considered, the full range goes from less than 100,000 to 750,000 cases. The forecasting models, which were based on four different forecasting methods (extrapolation, back-calculation, macro-level, and micro-level simulation), vary considerably in terms of their comprehensiveness and the soundness of their empirical base. Other differences across the individual models concern specific assumptions made and the use of adjustments to correct for data deficiencies.

Assessing the major types of forecasting models on two major criteria—comprehensiveness and soundness of empirical base—showed that the micro-simulation models are the most comprehensive but, at present, lack a sound empirical base. Until the necessary empirical studies are conducted to provide this base, it would be difficult to specify a preferred forecasting method. Without judging the existing AIDS forecasts on the basis of a preferred forecasting method, we used the reasonableness of specific models' assumptions and their corrections for biases in the national surveillance data in order to specify a plausible range of forecasts for 1991.

Specifically, we believe that a more realistic forecast range lies between about 300,000 and 485,000 cumulative cases by the end of 1991. CDC's current "best estimate" of 285,000 cases thus falls just below the lower end of this range.

Three major conclusions of our study concern the available data on AIDS that forecasters must have if they are to make accurate predictions, as follows.

First, and perhaps most important, all of the models depend on the national surveillance data. Our review showed that a sizable net underrepresentation of the epidemic marred the surveillance data used by forecasters and that there has been a dearth of systematic methodological studies that accurately estimate the current sizes of the various undercounting problems and their impact on national forecasts and key subgroup data. Only by adjusting surveillance data for the likely undercount are plausible forecasts possible. New studies are needed if such adjustments are to be made with accuracy, and there is some question about the adequacy of resources that have been devoted to the surveillance system for cases of HIV-related disease at CDC.

Second, some of the forecasting models "assumed away" the possibility of any spread of the AIDS epidemic via heterosexual transmission. The existing national AIDS surveillance data show that there has been an increase in heterosexual-contact transmission cases, but this trend was not accessible to analysts outside CDC because of the limited detail that had been provided on CDC's public use tape for AIDS. Although the data on heterosexual risks has recently been expanded somewhat, information relevant to the interpretation of risk-group data (for example, the large number of "blanks" on the original case report forms) has not been made widely available. Thus, analysts outside CDC may have been hampered in assessing patterns of the epidemic across key risk groups.

Although it is not yet clear to what extent AIDS may spread into the non-drug-using heterosexual population, analyses by CDC analysts show that some spread has occurred. The trend appears to be concentrated within certain inner-city minority groups. Given this information, it seems overly optimistic to assume away all possibility of an increased number of cases in these populations. Forecasters, however, did not have access to this information.

Confidentiality concerns would be rightly considered in such issues as an expansion of geographic detail included in the public use data set—or for any other information that would represent realistic deductive-disclosure threats. However, such concerns may not be substantial for such issues as indicating the specific types of heterosexual risks (for example, IV-drug-using sex partner) that apply for AIDS cases that have already been coded in the heterosexual category on the public use data.

Third, micro-simulation models were judged most comprehensive in the sense that they measured six components of the epidemic. These models explicitly consider HIV transmission and the development of AIDS and show how these contribute to past, current, and forecasted levels of the epidemic. In addition, projected future occurrences for individual components can be adjusted by the forecaster, allowing assessments of the effect of potential changes. But, unfortunately, the empirical basis of these models was extremely weak, due to the lack of available information on specific components of the AIDS epidemic.[1]

[1] At least one proponent of the micro-model approach believes that because their models are "calibrated" to produce results that match actual trends in the national case data in recent years, these models are as reliable for the short-range as the extrapolation models that are more obviously or more directly based on the national case data.

If knowledge about AIDS transmission were improved, the most comprehensive (micro-simulation) models would be deemed superior to the others in the sense that micro-simulation models make explicit the forces that contribute to the forecast.

In summary, we conclude the following:

- To reduce uncertainty concerning the current size of the AIDS epidemic and to improve the information needed for all existing models that forecast the AIDS epidemic, methodological studies of the national surveillance data and the sizes of various undercount problems are needed.
- To facilitate sharing of information about the AIDS epidemic, especially information about risk-group membership, the public use data set and documentation should be expanded.
- To generate more useful forecasts of the AIDS epidemic in this nation, a sound empirical base should be provided for the most comprehensive forecasting models—that is, the micro-level simulation models.

Recommendations to the Secretary of Health and Human Services

To reduce uncertainty concerning the current size of the AIDS epidemic and to improve the information needed for all existing models that forecast the AIDS epidemic, methodological studies of the national AIDS surveillance data are needed to estimate the sizes of various undercount problems at the national level. At present, there are insufficient data available to estimate all sources of potential bias in the surveillance data; yet, it is clear that there has been a sizable underrepresentation of the epidemic at the national level. We therefore recommend that the Secretary of HHS require the Director of the Centers for Disease Control to (1) conduct rigorous national studies of the net effect of biases in the national AIDS surveillance data in order to improve national estimates of the current and projected size of the epidemic; (2) assess whether CDC's Surveillance Branch for tracking cases of AIDS and HIV-related diseases has sufficient staff and resources to plan, monitor, review, and disseminate such studies to the AIDS research community and forecasting modelers; and (3) incorporate additional information on risk-group membership into the CDC public use data set.

To generate accurate forecasts of the AIDS epidemic, a sound empirical base is needed for the most comprehensive forecasting models—that is, micro-level simulation models. We therefore recommend that the Secretary of Health and Human Services review existing and ongoing empirical studies of individual risk-group behaviors as well as of HIV transmission and the current level of HIV infection to determine where additional data are most needed.

Centers for Disease Control: Center for Infectious Diseases, AIDS Program—Surveillance of AIDS Cases[1]

Surveillance for cases of AIDS began in 1981 following publication of the first reports of the new disease. In 1983, the Council of State and Territorial Epidemiologists passed a resolution to make AIDS a reportable condition. The national surveillance system was intensified that year with the distribution of case report forms and the establishment of a formal and very specific surveillance definition of AIDS.

Surveillance of AIDS was also intensified through CDC's financial support to State and major city health departments for conducting active surveillance for AIDS cases. The first cooperative agreement award was made in September 1982. By the end of 1983, 15 areas were receiving cooperative agreement funding; by the end of 1984, 17 areas; by the end of 1985, 24 areas; by the end of 1986, 33 areas; and by the end of April 1988, all States, the District of Columbia, and most U.S. Territories had been awarded funds for active surveillance of AIDS.

Active surveillance programs for AIDS are multifaceted and include four major reporting sources of information: hospitals and hospital-based physicians, physicians in non-hospital practice, public and private clinics, and medical record systems (death certificates, tumor registries, hospital discharge abstracts, communicable disease reports, etc.). The major reporting sources employed in active surveillance frequently complement each other. Thus, an AIDS patient not identified by one source may be identified by another. Data gleaned from AIDS case reports have been important for identifying patterns of infection, for formulating and targeting prevention strategies, for use in developing timely guidelines for risk reduction, and for providing other information to the public, the scientific and public health communities, and members of high-risk groups.

Reported cases are categorized by an hierarchical system of transmission categories based largely on consideration of the most likely source of HIV infection. The most likely source should be exposure to the population with the greatest prevalence of HIV-antibody positivity and by the route that most efficiently transmits HIV.

The original surveillance case definition, based on then-available knowledge, provided useful epidemiologic data on severe HIV disease. To ensure a reasonable predictive value for underlying immunodeficiency caused by what was then an unknown agent, the indicators of AIDS in

[1] Prepared by CDC for inclusion in this report.

the old case definition were restricted to particular opportunistic diseases diagnosed by reliable methods in patients without specific known causes of immunodeficiency. After HIV was discovered to be the cause of AIDS, however, and highly sensitive and specific HIV-antibody tests became available, the spectrum of manifestations of HIV infection became better defined, and classification systems for HIV infection were developed. It became apparent that some progressive, seriously disabling, and even fatal conditions (e.g., encephalopathy, wasting syndrome) affecting a substantial number of HIV-infected patients were not subject to epidemiologic surveillance, as they were not included in the AIDs case definition. The case definition was revised in 1985 and again in 1987 to include additional diseases in persons with laboratory evidence for HIV infection. In order to be sensitive to changing diagnostic practices, the 1987 revision also permitted the reporting of clinically (presumptively) diagnosed cases with laboratory evidence of HIV infection.

Assessment of the level of case ascertainment is essential for reliably interpreting AIDS case surveillance data. Past formal validation studies, albeit geographically limited, documented the completeness of reporting of cases meeting the AIDS definition at 89% or greater. Other studies conducted in two States without active surveillance determined completeness of reporting to be 63% and 61%. A follow-up evaluation in one of these States following enhancement of surveillance activities suggests that the completeness of reporting has improved to 97%. A number of States have conducted projects to evaluate surveillance activities with varying results, but these projects have not been critically reviewed. Because results from many of these studies are not comparable and because changing geographic patterns of disease limit the reliability of previous studies, additional evaluations are needed to effectively assess the completeness of national reporting.

CDC collects AIDS surveillance data under an assurance of confidentiality which prohibits the unauthorized release of individually identifiable information regarding AIDS cases. Cases are identified through assignment of a Soundex code, an alpha-numeric system based on the patient's last name, date of birth, and assigned patient number. Summary tabulations of AIDS surveillance data are released monthly through the "HIV/AIDS Surveillance Report" and quarterly through a detailed public use data set. Cross-tabulations of data within States and major cities are provided in the public use data set; however, cells containing numbers less than or equal to 5 are deleted.

Prediction Formulas

Extrapolation forecasts for which the best-estimate prediction formulas have been published include the following:

CDC

Both the 1986 and 1988 forecasts are based on a quadratic formula and Box-Cox transformation for period incidence. The specific 1988 formula is

$$(Y_t^p - 1)/p = 29.58 + 1.289t - 0.0145t^2$$

where p = 0.29
t = calendar quarters, with t=0 for 2nd quarter, 1985.
Y = incidence, that is, cases diagnosed, in the t^{th} time period.

Model projections were subsequently inflated by 19% (1988).

Fuhrer

Fuhrer's "best estimate" forecast is based on the following logistic formula:

$$f(t,p_1,p_2,p_3) = \frac{p_1}{1 + e^{(p_2 + tp_3)}}$$

t = calendar quarters, starting in 1982.

Values of p_1, p_2, p_3 were chosen to minimize the sum of the squared deviations of observed incidence Y from this function; however, the resulting values for these p's were not included in Fuhrer's paper.

Los Alamos (Cubic)

The accumulated number of AIDS cases (A) for time (t) is estimated by

$$A(t) = 174.6(t - 1981.2)^3 + 340$$

where t = date in calendar time (for example, 1991.99).

In deriving this formula, a Box-Cox transformation was initially used with nonlinear regression; however, those results approximated the cubic formula.

Hellinger

The best-estimate forecast is the midpoint between the lower and upper bounds calculated according to the following formulas for period incidence (that is, C represents new cases diagnosed in time interval T):

Lower-bound:

$C_t = 183 + 21.16T + .118T^2$

Upper-bound:

The square root of $C_t = 15.16 + .49T$

T = 4-week periods, beginning with the first such period in 1984. Because the formulas were derived based on reported cases (instead of diagnosed cases) per time interval, an inflation factor of 1.25 was used. To account for underreporting and for illnesses not defined as AIDS until September 1987, an additional inflation factor of 1.2 was used.

HCFA (Klemm)

CDC's 1986 estimate was used with an inflation factor of 1.2 to account for underreporting and underascertainment.

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