
Update/Le point

Public health surveillance of AIDS and HIV infections*

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The general methods used for public health surveillance of acquired immunodeficiency syndrome (AIDS) cases and of human immunodeficiency virus (HIV) infections are no different from those used for other diseases and infections. However, the methods used must be adapted to the unique epidemiology, wide variation in prevalences, and the very long incubation period of HIV infections. In addition, the severity of AIDS and the extreme social and personal implications of identifying HIV-infected persons make surveillance of AIDS cases and HIV infections much more difficult and place paramount importance on issues such as anonymity and confidentiality.

Information on the occurrence of AIDS cases is essential for planning and developing the clinical and laboratory facilities needed for treatment and care of patients with the disease. However, surveillance of AIDS cases is of limited value for assessing the magnitude and future trends of the pandemic because the number of such cases detected, diagnosed, and reported reflect HIV infections that were acquired many years previously. In addition, there are significant problems associated with the accuracy, completeness, and timeliness of most AIDS case-reporting systems.

Routine HIV surveillance systems are being developed worldwide. Such systems must be adapted to the prevailing epidemiological situation; and the sampling methods used in populations where the prevalence of infection is very low must necessarily differ from those where it is moderate to high. Large-scale population serosurveys are very costly, and the results from such surveys may also be of limited accuracy because of serious problems of selection and participation bias. Furthermore, they may become outdated rapidly in areas where a high incidence of HIV infection occurs. WHO has therefore recommended the development of sentinel systems for routine public health surveillance of HIV infection.

Introduction

Public health surveillance can be defined as "the collection, analysis, and dissemination of data relevant to the prevention or control of a public health problem". The general methods used for public health surveillance of acquired immunodeficiency syndrome (AIDS) cases and human immunodeficiency virus (HIV) infections are no dif-

ferent from those used for other diseases and infections. However, the methods used must be adapted to the unique epidemiology, wide variation in prevalences, and the very long incubation period of HIV infection. In addition, the severity of AIDS and the extreme social and personal implications of identifying HIV-infected persons make surveillance of AIDS and HIV infections much more difficult and make issues such as anonymity and confidentiality of paramount importance.

This paper describes the development of public health surveillance of AIDS cases and HIV infections, placing emphasis on methodological issues and problems. Surveillance of AIDS and HIV infection in infants and young children is not included, because defining paediatric AIDS and diagnosing HIV infection in infants pose different and more complex problems, most of which have not yet been adequately resolved.

* A French translation of this article will appear in a later issue of the *Bulletin*.

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Surveillance of AIDS cases

Case definitions

Public health surveillance of AIDS cases began in 1982 with the development of an AIDS case definition for reporting purposes by the Centers for Disease Control (CDC) (1). About a dozen diseases—primarily *Pneumocystis carinii* pneumonia, Kaposi's sarcoma, and other, mostly severe opportunistic infections—were accepted as indicators of an underlying immunodeficiency. Because of the need for specificity, it was recognized from the start that this definition was not likely to include the syndrome's full clinical spectrum. The initial definition was modified slightly in 1985 (2) and was adopted for global use by WHO in 1986 (3). In late 1987, major revisions were made to place greater emphasis on HIV infection status, to include additional indicator diseases, and to accept presumptive diagnoses of some of the indicator diseases (4, 5).

The CDC/WHO surveillance definition of AIDS could not be used in most developing countries because adequate laboratory facilities were generally not available for the histological or cultural diagnosis of those specified diseases that met this relatively rigid definition. In addition, the indicator diseases in various regions tended to reflect the indigenous infectious agents present there, and these differed somewhat from area to area. In October 1985, an AIDS workshop was held in Bangui, Central African Republic, which led to a WHO clinical definition of AIDS.^a In recent years, with the ever increasing availability of HIV antibody testing, some African countries have added laboratory criteria of HIV infection to the existing "Bangui" case criteria for diagnosis and reporting of AIDS cases. Similar modifications to the surveillance definition(s) have been made in many other regions of the world.

Reporting of AIDS cases

Surveillance for AIDS cases, primarily via systems that rely on "passively" receiving reports of cases, is being carried out by virtually every country and reported to the WHO Global Programme on AIDS. Reports of AIDS cases from most of the industrialized countries of Europe, North America, and Oceania are based primarily on the CDC/WHO definition; those from Africa are, in general, based on nationally adapted versions of the WHO clinical

(Bangui) definition; and those from other countries involve a combination of these definitions (6).

Information on the occurrence of AIDS cases is essential for planning and developing clinical and laboratory facilities, in addition to the expertise needed for the treatment and care of AIDS patients. However, it should be noted that surveillance of AIDS cases is of limited value for assessing the magnitude and future trends of the pandemic because such cases reflect HIV infections that were acquired many years previously. In addition, there are significant problems related to the accuracy, completeness, and timeliness of AIDS case-reporting systems.

Accuracy of reports. Some of the many diseases or conditions that are considered to be reliable indicators of the underlying immunodeficiency caused by HIV infection are themselves difficult to diagnose accurately. Also, the sensitivity of the CDC/WHO definition for identifying the severe immunodeficiency caused by HIV is not known; however, the definition was not designed for maximum sensitivity.

Studies to evaluate the specificity of the CDC/WHO definition that are based on HIV seropositivity indicate that it is very specific; there are few false-positive results (4). Evaluation of the WHO clinical definition of AIDS in several studies in Africa that were based on HIV seropositivity suggest also that it is reasonably specific (80–90%) in areas where the prevalence of HIV infections is moderately high (1–2% or more of the general adult population), but that its specificity is extremely poor in areas where the general prevalence of HIV infections is very low (7, 8). It should be emphasized that surveillance definitions for AIDS were not intended to be reliable indicators of HIV infection. Thus, in areas where the prevalence of HIV infection is very low, the WHO clinical definition primarily identifies patients with tuberculosis, severe malnutrition, or diarrhoea.

Completeness of reporting. The variation in the accuracy of the various case definitions to identify AIDS cases is of minor importance relative to the extent of incomplete ascertainment and failure to report AIDS cases that exist in many areas. Studies based on the completeness of reporting in the USA showed that about 80% of AIDS cases that met the CDC/WHO definition were diagnosed or reported (9, 10). In other industrialized countries, the completeness of reporting may be higher or lower, but the majority of diagnosed cases are probably eventually reported. In Latin America there are wide variations in the completeness of AIDS reporting and extensive underreporting ($\leq 50\%$) of diagnosed cases is the rule in many countries. In Africa reporting of AIDS cases has been incomplete for a variety of reasons, includ-

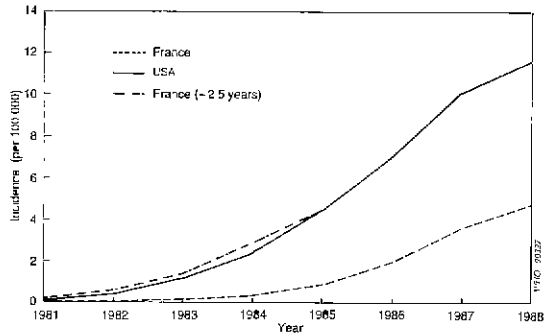
^a World Health Organization. *Workshop on AIDS in Central Africa, Bangui, Central African Republic, 22–25 October 1985*. Unpublished document WHO/CDS/AIDS/85.1

ing: the reluctance of some governments to officially recognize the existence of the disease or the magnitude of the epidemic; the general lack of diagnostic laboratory facilities; relatively poorly developed public health reporting systems; and limited access of large segments of the population to health-care facilities where AIDS might be diagnosed and reported. Perhaps only 10–20% of all adult cases that have occurred in Africa have therefore been reported to WHO (6, 11).

Reporting delays. In industrialized countries, it may take from a few weeks to several months for the report of a case of AIDS to be recorded at the national level, while in many developing countries it can take a year or longer. Furthermore, the delays are not always predictable and may vary substantially with time. In general, as the number of AIDS cases in a country increases the completeness of reporting decreases and the reporting delays increase progressively. By June 1990, a cumulative total of over 263 000 AIDS cases (almost all in adults) had been reported to WHO. Of these, almost 40 000 were diagnosed and reported in 1989. However, reports of AIDS cases that had been diagnosed as long ago as the early 1980s were only received by WHO in 1989. Based on observed delays in official reporting of AIDS cases to WHO, it can be projected that by early 1991 the number of reported cases that were diagnosed in 1989 will be approximately double the level received in 1989 (as of June 1990, the 1989 total was over 75 000 globally).

Comparisons of reported data. Reported data on AIDS cases have been used frequently to compare the magnitude of the epidemic in different countries. The obvious problems in making such comparisons are: the prominent differences in the accuracy of the reported data, which depend on the definition(s) used; the completeness of reporting; delays in reporting; and differences in epidemiological patterns, i.e., the major risk behaviours and relative size of the risk "groups" involved. In addition, the possible different "ages" of the HIV epidemics in the areas being compared must also be taken into account. For example, the epidemiological patterns of the HIV epidemic in the USA and France are somewhat similar; and the accuracy and completeness of reporting in these two countries are probably also comparable. It is generally acknowledged that in the USA the HIV epidemic started approximately 2–3 years before commencing in France. In 1988 the annual incidence of reported AIDS cases was 11.6 per 100 000 population in the USA and 4.6 per 100 000 in France. However, if the annual incidence curve of reported AIDS cases in France is shifted back 2.5

Fig. 1. Annual incidence of AIDS cases in the USA and France from 1981 to 1988, reported to WHO by January 1990.



years, the curves for the USA and France become almost identical (Fig. 1).

Surveillance of HIV infections

Measuring the prevalence and incidence of HIV. The prevalence of HIV is given by the number of HIV-infected persons in a population. The period prevalence is expressed as the total number of HIV-infected persons over a specified period of time (usually 1 year), whereas the point prevalence refers to the total number of HIV infections in as short a period as possible (this should be no more than 1–2 months). The incidence of HIV infections is the number of new HIV infections over a specified period of time, often 1 year.

For HIV infections, measurement of the period prevalence over 1 or 2 years is inappropriate and misleading because the most up-to-date total number of such infections, i.e., the point prevalence, is the important figure needed by public health programmes. The incidence is the most important indicator of the trend of the HIV epidemic in any given population, but usually it can only be measured for a few population groups that engage in high-risk behaviours; in most situations, the incidence of HIV infection is generally too low to be measurable.

Table 1 shows the prevalence and incidence of HIV expected in selected population groups in high- and low-prevalence areas. In high-prevalence areas, measurement of both the prevalence and incidence are feasible for high-risk groups; however, in low-prevalence areas it is difficult enough to measure the prevalence with any degree of accuracy or confidence, while the measurement of incidence is virtually impossible.

HIV infections are not randomly distributed in human populations. Relatively high HIV prevalences

Table 1: Prevalence and incidence of HIV in selected populations

Population	Pattern II ^a		Pattern III ^b	
	Point prevalence (%)	Annual incidence (%)	Point prevalence (%)	Annual incidence (%)
Prostitutes	> 50	2-30	1-2	<1
Military personnel	20-30	1-4	<1	<1
Pregnant women	10-20	1-2	<0.1	<0.01

^a High prevalence area

^b Low prevalence area

(from a few percent to over 50%) can be found among persons who have had multiple sexual partners, especially homosexual or bisexual men who have had many male sexual partners, and persons who frequently share injection equipment for intravenous drug use. However, the prevalence of HIV in the general populations of industrialized countries is very low and may range from almost zero to 1 per several thousand. Thus, accurate and cost-effective public health surveillance of HIV infections will require appropriate sampling strategies to accommodate the geographical distributions and wide range of prevalences in different population subgroups.

Until now, public health surveillance data on HIV have been obtained from a variety of uncoordinated sources. Many of these data have been gathered from samples of selected population groups. Thus, the data obtained are usually not comparable from one area to another or between different studies; in addition, they do not provide good baselines for future monitoring of HIV infection. Below are outlined several key aspects of public health surveillance of HIV infection.

Objectives of HIV testing or screening

HIV antibody testing or screening has two broad but distinct objectives: case-finding and public health surveillance. In case-finding, the primary objective is to ascertain the HIV-infection status of a specific person for appropriate medical treatment or public health follow-up and action. For public health surveillance, in contrast, the objective is to determine the prevalence, distribution, and trends of HIV infection in a group or population. For this purpose it is not necessary to know the identity of any specific individual. While many workers hold that both objectives can and should be achieved in any HIV testing or screening activity, it has been shown that blood

samples collected for HIV testing and given personal identifying information provide very misleading data about the true prevalence of HIV infection in a specific population (12, 13).^b Many epidemiologists do not favour combining case-finding and surveillance because this usually compromises both objectives. In general, most programmes or activities to identify HIV-infected persons cases can identify only a small proportion of all such persons in the population. If the primary objective of a study is public health surveillance of HIV infection in a given population or group, priority should be given to collecting accurate data. Such efforts should thus not be compromised by attempts to identify the infection status of specific individuals.

Sensitivity, specificity, and predictive values of HIV antibody tests

The sensitivity of an HIV antibody test is a measure of its accuracy to detect HIV antibodies that are present in a sample; the specificity of the test is its accuracy in confirming the absence of HIV antibody when none is present. Ideally, a test should be 100% sensitive and 100% specific. In practice, however, no biological test meets these requirements, but current HIV antibody tests are among the most sensitive and specific tests available. Under ideal laboratory conditions, most commercially available HIV antibody tests have greater than 99% sensitivity and specificity; these are inherent properties of a given test and should not vary significantly unless caused by human errors in the laboratory.

The predictive value of a positive HIV antibody test is the likelihood that an individual truly has HIV antibodies if his or her test is positive. The predictive value depends, in part, on the sensitivity and specificity of the test used, but more importantly it is a function of the prevalence of HIV infection in the population tested. For example, in a population with no HIV infections, any positive HIV antibody test will, by definition, be a false positive: in this case, the predictive value of a positive test is zero. However, as the prevalence of HIV infection in the population approaches about 1% (which is high), the predictive value of a positive test becomes very high. This is because currently available HIV antibody tests ordinarily result in very few false positives, and the low rate of false positives, i.e., 1 per 1000 or a specificity of 99.9%, remains relatively constant. In contrast, the number of true positives is directly proportional to the prevalence of HIV in the popula-

^b San Francisco Department of Public Health, AIDS Office. *HIV seroprevalence report*, Vol. 1, No. 1, January 1990.

tion. The increasing predictive value of a positive test as the prevalence of infections becomes greater is shown by the data in Table 2 for a test that has a specificity of 99.9%. The number of false positives per 100 000 persons screened remains relatively low, at 100 or fewer; however, the number of infected persons who would be expected to have HIV antibodies increases markedly as the prevalence of HIV infection increases.

For surveillance purposes, HIV tests do not need to be as accurate as would be required for clinical purposes. However, when the population prevalence of HIV is very low, all positive specimens should be routinely retested using supplementary tests, because the predictive value of a positive test in such circumstances is very low.

Table 2: Positive predictive value of HIV test results according to the prevalence of HIV (per 100 000 persons screened)

Prevalence of HIV	No. infected	No. not infected	No. of false positives	Positive predictive value (%)
0.01	10	99 990	100	10
0.1	100	99 900	100	50
1.0	1000	99 000	99	91
10.0	10 000	90 000	90	99
20.0	20 000	80 000	80	> 99

HIV testing with or without personal identifying information

Blood samples for HIV antibody testing or screening can be collected with names (nominal collection) or without names or personal identifying information (anonymous or non-nominal collection) (Fig. 2). For case-finding purposes, individual identifying information clearly must be collected and eventually linked with the results of HIV antibody tests. From the epidemiological perspective, the advantages and disadvantages of nominal or non-nominal collection of blood for HIV testing are presented in detail in the WHO guidelines developed for monitoring HIV in populations.^c Nominal methods used in any open or free population may yield results that do not accurately reflect the true prevalence of HIV in the population, because a variable number of persons may, if given a choice, elect not to be tested. As noted earlier, for public health surveillance purposes, it is

Fig. 2. Outline of the methods of obtaining blood samples for HIV screening.

NON-nominal (anonymous)

- Unlinked anonymous
- Voluntary anonymous

NOMINAL

- Voluntary confidential
- "Routine" confidential
- Mandatory
- Compulsory

WHO 90329

not necessary to know the HIV infection status of individuals. Methods that do not collect identifying information or that unlink such information from the blood sample before HIV tests are performed can provide data for monitoring the prevalence and patterns of HIV in specified target or sentinel groups. Of the two non-nominal methods shown in Fig. 2, the voluntary anonymous method may not provide accurate surveillance data because the individuals who wish to be tested in this way may not be representative of the risk group to which they belong.

Unlinked anonymous screening may be more accurate for measuring the prevalence of HIV in a specific population (14). If a specific target or sentinel population group, such as individuals who are attending a special clinic, are selected for surveillance, efforts should be made to ensure to the maximum extent possible that the results are representative of the total population who are attending the clinic. Unlinked anonymous screening has the following characteristics: it uses blood specimens collected for other purposes; it ensures anonymity by eliminating or unlinking identifying data; it avoids the need for informed consent; it eliminates the need for counselling and social support services; and most importantly, it minimizes participation bias.

^c *Unlinked anonymous screening for the public health surveillance of HIV infections. proposed international guidelines.* WHO unpublished document GPA/SFI/89.3.

Table 3: Data illustrating the participation bias in HIV testing

HIV testing response:	No. tested	No positive
<i>STD patients*</i>		
Consented	782	8 (1.0) ^b
Refused	167	9 (5.4)
Total	949	17 (1.8)
<i>Pregnant women</i>		
Consented	36 053	4 (0.011)
Refused	50	1 (2.0)
Total	36 103	5 (0.014)

* STD=sexually transmitted disease.

^b Figures in parentheses are percentages

The data presented in Table 3 show how use of unlinked anonymous screening identified and measured participation bias in a high-risk and in a very low-risk population. In the first example shown, from a sexually transmitted disease (STD) clinic in New Mexico, all clinic attendees were offered HIV tests (11). Almost 800 men consented to be tested, and of these, eight were positive, which corresponds to an HIV prevalence of 1%. Of the 167 men who refused an HIV test, a portion of their blood sample that had been collected for syphilis testing was also tested for HIV antibody after all identifying data had been removed (unlinked). Of this group, nine were HIV seropositive, which corresponds to a prevalence of greater than 5%. If unlinked anonymous screening had not been carried out, the HIV seroprevalence for this clinic would have appeared to be 1%, when it was, in fact, almost 2%. In the second example in Table 3, more than 36 000 pregnant women in Norway were offered HIV testing, and almost all accepted (13). A very low prevalence—about 1 per 10 000 was found for those who agreed to be tested. Fifty women refused to be tested, but unlinked testing of their blood specimens collected for other routine purposes revealed one seropositive, i.e., a 2% positive rate.

Although unlinked anonymous HIV testing may provide more accurate data, the method has the following limitations: it cannot eliminate potential selection bias; data on high-risk behaviour and other important variables are not available and cannot be collected retrospectively; HIV-infected persons cannot be contacted and informed about their infection status; and only groups that have blood taken for other purposes can be studied.

A systematic approach to HIV surveillance

Since it is generally not feasible to monitor the trends in HIV infection in the total population, public

health surveillance of such infection must rely increasingly on the routine and consistent collection of data from sentinel groups. Such surveillance needs to focus on easily defined, accessible population groups that are comparable from area to area. Since the basic purpose of sentinel surveillance is to detect changes in the prevalence of HIV in the groups selected, the target group need not be representative of the general population. If different sentinel groups are monitored uniformly over a period of time at selected sites, the data collected will provide information on HIV trends in those groups, and in addition provide most of the data required for the design and direction of HIV/AIDS control programmes. The sentinel populations selected should allow for the monitoring of major HIV risk behaviours or factors known to be prevalent in any given area.

Lot quality assurance (LQA) sampling methods may be an economical method for HIV sentinel surveillance in low-prevalence areas. Such methods were originally designed to sample batches of manufactured products for quality control (15). The basic strategy assured buyers that they could reject a batch of products if it contained more than a specified proportion of defectives; at the same time, the manufacturer did not have to reject a batch unless a certain proportion of goods was defective. Such an approach can be readily extended to a sentinel surveillance system for HIV infection, since unless a pre-determined proportion of persons among a specified target or sentinel group are found to be infected, one can conclude that the level of infection in the target group is not above a preset threshold. The use of LQA sampling techniques for HIV surveillance greatly reduces the sample sizes needed to determine whether the prevalence of HIV in a sentinel group, such as patients attending an STD clinic, is not likely to be above a pre-determined critical value—a level that can be set or changed as needed. In areas where the prevalence of HIV is very low (≤ 1 per 1000), LQA sampling techniques are more efficient than methods to estimate the precise prevalence of HIV infection.

Below is outlined a possible approach to public health surveillance for HIV infection using LQA sampling techniques in sentinel populations.

- In areas where HIV infection is believed to be very low, priority for public health surveillance should be given to those persons or population groups with the highest risk behaviour(s). Universally, these include individuals who have had multiple sexual partners. Blood for HIV screening from this "risk-group" can be most easily collected in STD clinics or similar facilities. If intravenous drug use is also prevalent, blood samples should be collected from users at special clinics.

● Quarterly or semiannual sampling of the highest-risk groups in those geographical areas with the highest density of such groups should usually be sufficient. An exception to this scheme may be risk groups such as intravenous drug users, for whom more frequent monitoring may be necessary. The sample sizes required for LQA statistics are much smaller than those for conventional sampling statistics. For example, if it is desired to be 95% confident that the prevalence of HIV infection in a specified population is no more than 1 per 1000 (0.1%), a sample size of about 3000 would be sufficient with LQA statistics if none of the 3000 individuals sampled are HIV positive. In contrast, to be similarly confident that the prevalence was 1 per 1000 ($\pm 50\%$), using conventional sampling statistics, a sample size of over 15 000 would be needed. As the prevalence of HIV infection increases, however, the sample sizes required to carry out conventional sampling methods begin to come within the scope of public health surveillance programmes.

Summary and conclusions

AIDS surveillance

Reported numbers of AIDS cases are of limited value for public health planning. Significant "adjustments" usually have to be made to the reported data so that they more accurately reflect the real situation. In areas where the reporting infrastructure is very weak, estimates of actual AIDS cases must be made virtually independently of the official data. For public health purposes, the surveillance definition of AIDS should be kept as simple and consistent as possible, and suggestions for increasing the sensitivity and/or specificity of definitions of AIDS made by laboratory or clinical specialists need to be evaluated critically. Marked changes were made in the 1987 revision of the CDC/WHO surveillance definition, and these have resulted in temporal "distortions" of the reported case curve, which in turn, have caused confusion and debate about trends in the occurrence of AIDS cases. For example, it has been estimated that 15–25% of AIDS cases reported in the USA and Spain during 1988, using the 1987 revised definition, would not have been diagnosed as AIDS had the older definition been applied strictly (16, 17).

It is worth re-emphasizing that current definitions of AIDS were developed for public health surveillance purposes; as such, they are of limited value for most clinicians, who need greater sensitivity and specificity. For clinical treatment and for research purposes, a more detailed and sophisticated clinical classification or staging system is needed, and several have been developed. WHO is in the process of

developing a clinical research classification/staging system that can be used for treatment trials, which may also have prognostic value. However, such a system is not intended to replace existing public health surveillance definitions of AIDS.

HIV surveillance

Estimates of the prevalence of HIV are essential for monitoring the epidemiological patterns and scope of the HIV/AIDS pandemic. In addition, future cases of HIV-related diseases, including AIDS, will depend on the number of persons infected with the virus. HIV seroprevalence data obtained by the majority of studies performed during the 1980s must be interpreted and compared with extreme caution because of the wide differences in the survey methods used and in the populations covered. Despite these differences, thousands of HIV serological surveys and studies of several million persons have been carried out over the last 5 years: collectively, they have been used to describe the distribution and prevalence of HIV infections in most areas of the world.

Routine HIV surveillance systems are being developed worldwide. Such systems must be adapted to the prevailing epidemiological situation: the sampling methods used in populations with very low HIV prevalence must necessarily differ from those where it is moderate to high.

Large-scale population serosurveys demand considerable time and resources, and their results may be of limited accuracy because of serious problems arising from selection and participation bias. Furthermore, they may become rapidly outdated in areas where there is a high incidence of infection. WHO has therefore recommended the development of sentinel systems for routine public health surveillance of HIV infection.

Sentinel surveillance involves the routine study of well-defined and accessible population groups. Initially those groups who are at increased risk of HIV infection should be selected for such surveillance, and a predetermined number of individuals from each group should be consistently sampled. The sampling frequency will depend on the estimated incidence of infection in the sentinel group, and the predetermined number of samples should be collected in as short a period as possible to measure more accurately the HIV point prevalence. LQA sampling techniques can be used for sentinel surveillance of populations with a low prevalence of HIV. In collecting blood samples from sentinel groups, attempts should be made to minimize participation bias in order to produce reliable estimates of HIV prevalence. During the last few years, the use of unlinked anonymous screening of sentinel groups has been

increasingly advocated as an accurate and cost-effective method for the public health surveillance of HIV infection.

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