

CHAPTER FOUR

SURVEILLANCE

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Surveillance of infectious diseases is the continuous systematic collection of data on illness or infections in a defined population to monitor the incidence or prevalence of a disease or a behavior that is placing people at risk of disease or ill health. Although surveillance originally focused on infectious diseases, especially the major epidemic conditions, the activity has been broadened to include noninfectious diseases, such as cancer, heart disease, renal disease, and strokes. More recently, routine surveillance data have been collected on risk factors, disability, behavior, and health practices.

The Centers for Disease Control and Prevention (CDC) in 1986 defined *epidemiologic surveillance* as follows^{1,2}:

Epidemiologic surveillance is the ongoing systematic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know. The final link in the surveillance chain is the application of these data to prevention and control. A surveillance system includes a functional capacity for data collection, analysis, and dissemination linked to public health programs.

This concept of surveillance differentiates surveillance from occasional surveys and from planned comprehensive research programs. Also, a surveillance program involves analysis, interpretation, and dissemination of the data for the purpose of improving the health of the population and preventing disease. Therefore, surveillance needs to be selective, planned, and tailored to meet a specific goal in the prevention of disease.

This chapter reviews the history of the development of surveillance systems and their applications to the recognition, control, and prevention of infectious disease. Several current surveillance programs are described, along with their application to the prevention of infectious disease.

History of Surveillance

The responsibility of local governments to control and prevent disease in the population dates back to early times. Governments assumed responsibility for disease control by identifying possible sources of disease and quarantining infectious cases to prevent further spread.³ Illness was monitored, regulations were enacted to prevent pollution of streets and public water supplies, and instructions were specified for burial and food handling. Unfortunately, this was not always based on a sound understanding of disease transmission as when the Mayor of London ordered the slaughter of cats and dogs to slow the bubonic plague epidemic of 1665. Cases continued to rise as rat populations were unchecked over the summer and only slowed when flea populations died off in the fall. The epidemic was finally ended when the crowded houses of London, which sustained the epidemic, burned in the Great Fire of London on September 2, 1666.⁴

In the 1600s, John Graunt published the bills of mortality for the surveillance of disease in London.⁵ In Germany, Johann Peter Frank advocated that public health surveillance include maternal and child health, injuries, occupational illnesses, and school health.⁶

The modern concepts of surveillance were developed by William Farr in Great Britain. He was the superintendent of the Statistical Department of the Registrar General's Office of England and Wales from 1839 to 1879. Farr collected, analyzed, and published mortality and morbidity statistics for England and Wales and reported the data to responsible public health authorities and the general public.⁷

Surveillance in the United States

Infectious disease surveillance in the United States began soon after the colonies were established. In 1741, Rhode Island passed legislation requiring tavern keepers to report contagious disease among their patrons. Two years later, a law was passed requiring the reporting of smallpox, yellow fever, and cholera.²

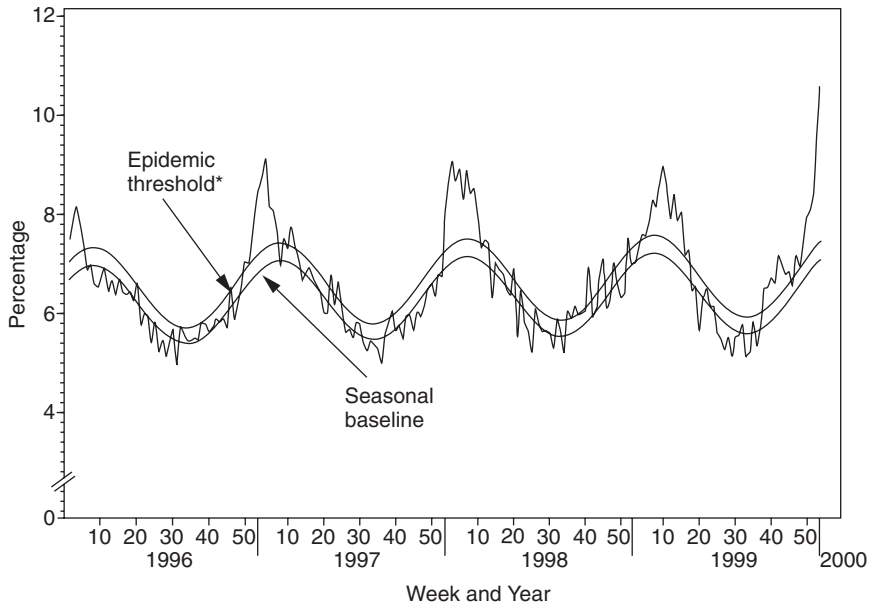
National disease surveillance began in 1850, when mortality statistics were first published by the federal government, based on the decennial census. The legal requirement to collect national morbidity data in the United States was initiated in 1878, when Congress authorized the US Public Health Service (USPHS) to collect reports of the occurrence of the quarantenable diseases, cholera, plague, smallpox, and yellow fever. In 1902 the Surgeon General of the USPHS was directed by Congress to provide forms for collecting data on these infectious diseases and officially reporting the surveillance data. Each state and municipality had laws requiring reporting of selected communicable diseases, such as smallpox, tuberculosis, and cholera.² In 1913, the state and territorial health authorities recommended that every state send weekly telegraphic summaries reporting infectious diseases to the PHS.⁸ In 1949, the National Office of Vital Statistics (NOVS) was established, and this office received, analyzed, and published infectious disease surveillance reports. These data were published in the official PHS journal, *Public Health Reports*. When this became a monthly journal, the NOVS issued a separate

weekly bulletin, the *Morbidity and Mortality Weekly Reports (MMWR)*, which was distributed to epidemiologists and others interested in health data. In July 1960, the responsibility for receiving morbidity reports on infectious diseases and publishing the *MMWR* was transferred from the NOVS to the Centers for Disease Control (CDC) in Atlanta.

The CDC was established in Atlanta after World War II. Its initial mission was to evaluate the health threat of malaria in the Southeastern United States at a time when many World War II veterans were returning from malaria-endemic areas in the Pacific and Mediterranean. Although reports of indigenous malaria were common in the 1940s and 1950s, when CDC established routine surveillance and evaluated the reported cases, it was determined that few of these reported cases could be confirmed and that malaria had already ceased to be an important endemic disease in the United States. Despite its negative finding, the rigorous malaria surveillance system convinced government and public health officials of the value of surveillance.

Alexander Langmuir, who became director of the epidemiology program at CDC in the early 1950s, emphasized the value of surveillance as a critical public health activity.⁹ In 1951, the Epidemic Intelligence Service (EIS) was established at CDC, which trained a cadre of field epidemiologists to investigate unusual epidemics anywhere in the United States upon invitation from the states.⁹ Subsequently, the value of systematic surveillance was demonstrated for other diseases. In 1955, inactivated polio vaccine, shown to be efficacious in a clinical trial, was used on a wide scale to control a polio epidemic.¹⁰ Tragically, several cases of polio appeared among those vaccinated in the previous 30 days. A review of reported cases implicated specific lots of vaccine that were incompletely inactivated and thus contained residual infectious polio virus.¹¹ This outbreak of vaccine-associated illness established the value of national surveillance of poliomyelitis, which continues to the present.

In 1957, a major pandemic of influenza occurred when a new genetic strain of influenza (Asian influenza, an H2/N2 recombinant virus) appeared, resulting in the establishment of influenza surveillance by the CDC. The CDC also included broader surveillance for deaths from pneumonia or influenza in 121 major US cities to enhance their ability to track influenza epidemics.¹² The CDC placed an emphasis on the development of novel methods for displaying surveillance data to ensure its ultimate value. Serfling and colleagues at CDC devised a clear and straightforward method for analyzing large surveillance databases.¹³ They plotted influenza case rates as an average over specific time periods that were compared with the same time period in the previous years when an influenza epidemic was known to be absent (Figure 4-1). Whenever two or three consecutive weeks exceeded the 95% confidence limits of mortality in a nonepidemic year, the excess mortality warned of a possible influenza epidemic. Subsequently, many other infectious diseases were targeted for surveillance, due either to the development of new vaccines (e.g., measles, rubella, or pertussis) and the need to monitor their effectiveness at a population level or to the emergence of new diseases (e.g., toxic shock syndrome, Reye's syndrome, Legionnaires' disease, Hanta virus pulmonary syndrome) that required ongoing epidemiologic investigation and control (Figure 4-2).



*The epidemic threshold is 1.645 standard deviations above the seasonal baseline. The expected seasonal baseline is projected using a robust regression procedure in which a periodic regression model is applied to observed percentages of deaths from P&I since 1983.

FIGURE 4-1 Percentage of mortality attributable to pneumonia and influenza (P&I) in 122 cities, by week of report United States, 1996–2000.

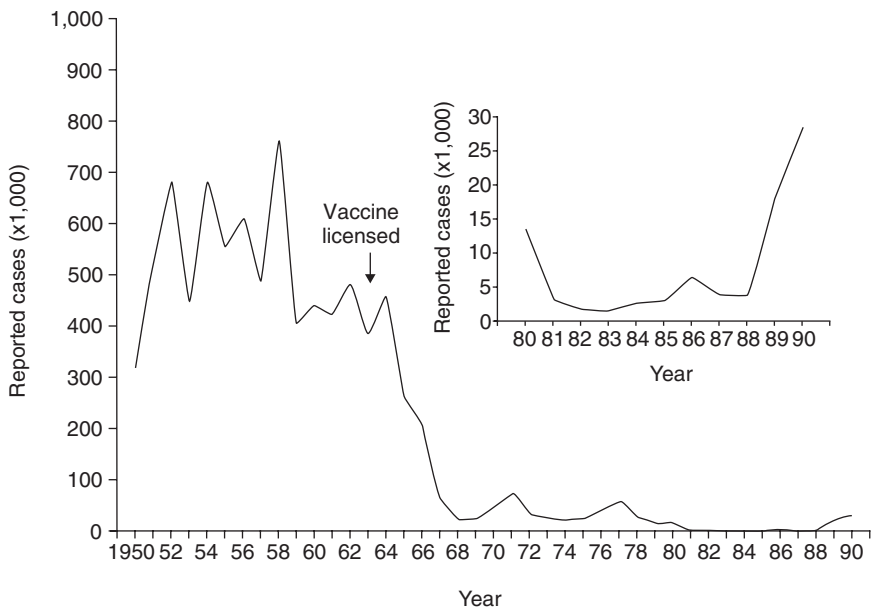


FIGURE 4-2 Measles (rubeola): by year, United States, 1950–1990. [Inset: Measles by year, United States, 1980–1990.]

Reportable Diseases

Currently, a total of 52 infectious diseases are officially reportable in the United States. These are listed in Table 5-1 in Chapter 5. The list of nationally reportable infectious diseases changes periodically. Diseases may be added to the list as new pathogens emerge or when a previously recognized pathogen becomes more important. Also, some diseases may be deleted from the list as their incidence or importance declines.

To standardize the cases reported to the CDC, official definitions of what constitutes a case have been published by CDC for all reportable and many of the nonreportable diseases.¹⁴ Some diseases require laboratory confirmation for diagnosis, regardless of clinical symptoms; whereas, others are diagnosed solely on clinical criteria. Examples of those requiring laboratory confirmation are infections from *Salmonella* species, *Shigella* species, *Escherichia coli* 0157:H7, and hepatitis A (HAV) or B (HBV) viruses; whereas, botulism, tetanus, varicella, and toxic shock syndrome are diagnosed solely by clinical criteria.

The official case definition of some diseases may be changed in some instances as new scientific information is accumulated. For example, as the HIV/AIDS epidemic has evolved, the official case definition of acquired immune deficiency syndrome (AIDS) has changed. Prior to the identification of the human immunodeficiency virus (HIV), the case definition of AIDS included the most characteristic, yet unique, clinical symptoms associated with the new disease, such as Kaposi's sarcoma, *Pneumocystis carinii* pneumonia, cytomegalovirus retinitis, or another opportunistic infection, plus signs of otherwise unexplained immune suppression as measured by CD4⁺ T-cell count. In 1987, a commercial test for the virus became available. However, it was not known what proportion of those infected with HIV would progress to severe disease. The case definition of AIDS was modified to require clinical symptoms, several of which were newly added in 1987, as well as being positive for the HIV virus.¹⁵ In 1993, research demonstrated that those with CD4 T-cell counts below 200/μL were at high risk for developing AIDS clinical symptoms. Based on this, the definition was changed to include those with clinical symptoms, *or* a CD4 T-cell count below 200/μL and HIV infection. Because a patient's risk of developing an opportunistic infection was affected by their immune state, their exposure to specific pathogens, and their level of prophylactic care, the low CD4 T-cell count case definition was felt to be a more consistent measure of HIV progression. Furthermore, the effective prophylactic care for HIV-positive patients was lowering the occurrence of opportunistic infections that suppressed the number of cases reported to CDC. The 1993 case definition sought to correct for this underreporting of AIDS cases by removing the previous requirement that an immune suppressed HIV-infected patient also have a documented opportunistic infection.¹⁶ Because many cases were reported solely on the basis of T-cell counts, there was a substantial increase in the number of officially reported AIDS cases in 1993 and 1994. However, the number of AIDS cases declined from this peak level in the subsequent years as the bolus of immune-suppressed, yet asymptomatic cases, were reported earlier than would have happened with the 1987 definition. To facilitate comparisons across time, data in research and surveillance reports must clearly state which

AIDS definition is being used. In fact, data are often reported using both the 1987 and 1993 definitions.

The case definition for tuberculosis has also changed several times during the past decades. The official case definition for tuberculosis raises some interesting issues. Patients with tuberculosis may respond to therapy and their disease resolve, only to reactivate at a later date. Should such a patient be reported twice? The current official practice for the CDC statistics is that such a patient should not be reported twice if the relapse occurs in the same year. However, if a patient responds and is released from therapy but relapses at a later date, both episodes should be reported as separate events. These examples are described in some detail to illustrate why it is important for epidemiologists to be familiar with the details of the case definition in order to understand and properly interpret the official statistics on reportable diseases and, especially, to evaluate temporal trends in infectious disease morbidity.

Types of Reports

Some diseases are reported to health departments as individual case reports, such as tuberculosis. Others are reported as the aggregate number of cases seen at a facility, such as varicella. For some diseases, the level of certainty of the diagnosis may vary from case to case. Sometimes, the appropriate laboratory specimens are not obtained or the patient is seen too late in the illness or after treatment, so that microbiologic confirmation of the disease is not possible. This level of certainty is reported on the case report, as in laboratory-confirmed case, clinically compatible case, or epidemiologically linked case.

Many diseases are reported *passively*, meaning that the health care providers report cases to health departments as a matter of routine. Other diseases are under *active surveillance* because of their potential public health importance. When active reporting is being done, health department personnel contact selected health care providers at regular intervals to solicit case reports. Active surveillance is particularly useful when an epidemic is suspected or in progress. For example, during an influenza-associated outbreak of Reye's syndrome, an epidemiologist might establish active surveillance for potential cases of Reye's syndrome by calling all of the neurologists in the area on a weekly basis. During an influenza outbreak, special surveillance methods are often instituted, such as monitoring school or workforce absenteeism, emergency room visits, or visits to select sentinel physicians' offices with compatible respiratory symptoms. These data are analyzed in concert with the pneumonia-influenza mortality statistics and published weekly in the *MMWR* during the influenza season or whenever the epidemic threshold is exceeded for several consecutive weeks.

Official CDC case definitions of three reportable diseases are shown in Table 4-1.¹⁴ The reader is referred to the CDC Web site (www.cdc.gov) for a comprehensive list of criteria for the 52 officially reportable diseases.

Guidelines for Evaluating a Surveillance System

Surveillance data are collected and analyzed to provide useful and current information on important infectious diseases to epidemiologists, health offi-

TABLE 4-1 Case Definitions for Infectious Disease Surveillance—Examples

Cases of infectious diseases are reported to health officials by health care providers, laboratories, and other public health personnel. Included below are case definitions for a few reportable infectious diseases.

- *Botulism*: Ingestion of botulinum toxin results in an illness of variable severity. Common symptoms are diplopia, blurred vision, and bulbar weakness. Symmetric paralysis may progress rapidly.
 - *Laboratory criteria for diagnosis*:
 - Detection of botulinum toxin in serum; stool on patients food
 - *Case classification*:
 - *Probable case*: A clinically compatible case with an epidemiologic link (e.g., ingestion of a home-canned food within the previous 48 hours)
 - *Confirmed case*: A clinically compatible case that is laboratory confirmed or that occurs among persons who ate the same food as persons who have laboratory-confirmed botulism.
- *Chlamydia trachomatis*: Infection with *C. trachomatis* may result in urethritis, epididymitis, cervicitis, acute salpingitis, or other syndromes when sexually transmitted; however, the infection is often asymptomatic in women. Perinatal infections may result in inclusion conjunctivitis and pneumonia in newborns. Other syndromes caused by *C. trachomatis* include lymphogranuloma venereum and trachoma.
 - *Laboratory criteria for diagnosis*:
 - Isolation of *C. trachomatis* by culture or
 - Demonstration of *C. trachomatis* in a clinical specimen by detection of antigen or nucleic acid.
 - *Case classification*:
 - *Confirmed case*: A case that is laboratory confirmed.
- *Varicella (chickenpox)*: An illness with acute onset of diffuse (generalized) papulovesicular rash without other apparent cause
 - *Laboratory criteria for diagnosis*:
 - Isolation of varicella virus from a clinical specimen or
 - Significant rise in serum varicella immunoglobulin G antibody level by any standard serologic assay
 - *Case classification*:
 - *Probable case*: A case that meets the clinical case definition, is not laboratory confirmed, and is not epidemiologically linked to another probable or confirmed case
 - *Confirmed case*: A case that is laboratory confirmed or that meets the clinical case definition and is epidemiologically linked to a confirmed or probable case

cials, clinicians, laboratory scientists, and the public to develop and evaluate methods for their prevention. Table 4-2 shows some sources of surveillance data on infectious diseases. To be useful for this purpose, surveillance systems need to have several qualities that promote efficiency and reliability of the data. The CDC has published a set of attributes and criteria by which to evaluate a surveillance system.¹⁷ These criteria can be used to evaluate an existing surveillance system or to establish a new system. The judgment of which criteria are most important depends on the primary purposes for which the surveillance data will be used. For example, surveillance systems that are designed to track an eradication campaign or to control an epidemic of a serious disease need to be comprehensive, rapid, and sensitive. The efforts and funding allocated to such a system will be much higher than surveillance for a less severe endemic disease. In this case, the surveillance system

TABLE 4-2 Sources of Surveillance Data on Infectious Diseases

Source	Description/Examples	
1. Mortality registration	Primary and underlying causes of death	1
2. Morbidity reporting	52 reportable diseases	
3. Epidemic/outbreak reports	Acute outbreaks reported to health department	
4. Laboratory	Laboratory reports are required for several reportable diseases, e.g., syphilis and salmonella.	2
5. Case investigations	Blinded surveys of HIV Individual cases of certain diseases are investigated, e.g., rabies, polio, plague.	
6. Nosocomial infection surveillance	NNIS;* all hospitals are required to do nosocomial infection surveillance to maintain licensure (Joint Commission)	3
7. Animal disease surveillance	Done by veterinary section of health department	
8. Adverse reactions to vaccines	VAERS, VSD*	4
9. Food-borne illness	FoodNet, PulseNet	
10. Vector populations	Targeted to specific vector-borne diseases	
11. Behavioral risk factors	DAWN* behavior risk factor survey	5
12. Targeted disease surveillance		
• Hepatitis	Sentinel Counties Study	
• Influenza	Pneumonia/Influenza Mortality in 121 US cities	
• Tuberculosis	Contact investigations of active cases	
• Syphilis	Contact investigation and “epidemiologic treatment” of exposed contacts	

*NNIS: National Noscomial Infection Surveillance Programs.

*VAERS: Vaccine Adverse Events Reporting System.

*VSD: Vaccine Safety Data Link.

*DAWN: Drug Abuse Warning Network.

may not count every case that occurs as long as those it does receive are representative of the populations at risk, and it can detect fluctuations in the disease incidence. A passive reporting system is the most cost-effective here, in which the criteria for a case are quite specific but less sensitive. This system is sufficient to detect major fluctuations in incidence, even when many cases go undetected or unreported.

The CDC recommended attributes of a surveillance system are as follows:

- **Sensitivity:** To what extent does the system identify all or most cases in a target population? As described above, good sensitivity may be more important for a surveillance system designed to control an outbreak or to evaluate an intervention than for monitoring disease trends.
- **Timeliness:** This refers to how rapidly reports are received, evaluated, and analyzed and the information provided to those in a position to intervene. This may be critical to control an outbreak of an acute disease.
- **Representativeness:** This refers to whether the likelihood of reporting a disease is the same within subgroups of the population or in different populations. If surveillance reports are not representative, this could affect the application of control efforts.

- *Predictive Value Positive*: This refers to the specificity of the case report. To what extent are the reported cases really cases? This is an important attribute of surveillance systems in most situations.
- *Simplicity*: This refers to both the system's structure and ease of operation. Surveillance systems should be as simple as possible, while still meeting their objectives. It is costly and burdensome to collect data that will not be used. A system that is too costly risks having its funds cut while a burdensome system may have poor compliance.
- *Acceptability*: This refers to the willingness of individuals and organizations to participate in the surveillance system. Obviously, this is a critical characteristic of all surveillance systems.
- *Flexibility*: This refers to a system's ability to adapt to changing information needs or operating conditions with little additional costs in time, personnel, or funding. Some disease-reporting systems are quite flexible and can accommodate the need to monitor new diseases. Generally, simple systems are more flexible. The system that reports the 52 diseases that are officially reported by all the states to the CDC is generally quite flexible. A newly recognized or emerging infectious disease usually can be added to the list. The decisions as to what diseases are to be reported are made regularly by the Council of State and Territorial Epidemiologists, and the definitions to be used to report cases are developed in consultation with the CDC.

Communication and Presentation of Data

The primary purposes of a surveillance system are to collect data on the health status and/or risk factors for disease in a population and to analyze, interpret, and utilize the data in a manner that will lead to prevention and control of disease. Therefore, a critical component of this activity is the interpretation and communication of the data in an ongoing fashion, so that health care providers or officials can take appropriate action when necessary. Investigations of epidemics of infectious diseases should occur promptly in a journal with a wide distribution to health professionals, the public, and the news media, such as *MMWR*, and should include (1) the results of the investigation, (2) the control measures instituted, and (3) interpretive comments to put the epidemic in context. Such reports have been successful in informing policies or procedures to prevent future epidemics.

Presentations of data on endemic infectious diseases are also important to assess progress or lack of progress toward a healthier society. The CDC issues annual reports on the epidemiology of several diseases, where longer-term trends are analyzed. Also, CDC regularly presents the weekly reports of infectious diseases in a graphic form, in which the number or rates of reported cases of several infectious diseases are compared with the number reported in recent weeks or in a comparable period in a previous year (Figure 4-3). Another method of data presentation is to show the temporal trends of disease incidence in reference to a targeted prevalence or incidence rate of the disease in the future, such as 2010. This type of graph allows the reader to determine whether a predetermined goal is likely to be met. These PHS goals were specified and published in the PHS publication, *Healthy People 2000* (Figure 4-4).

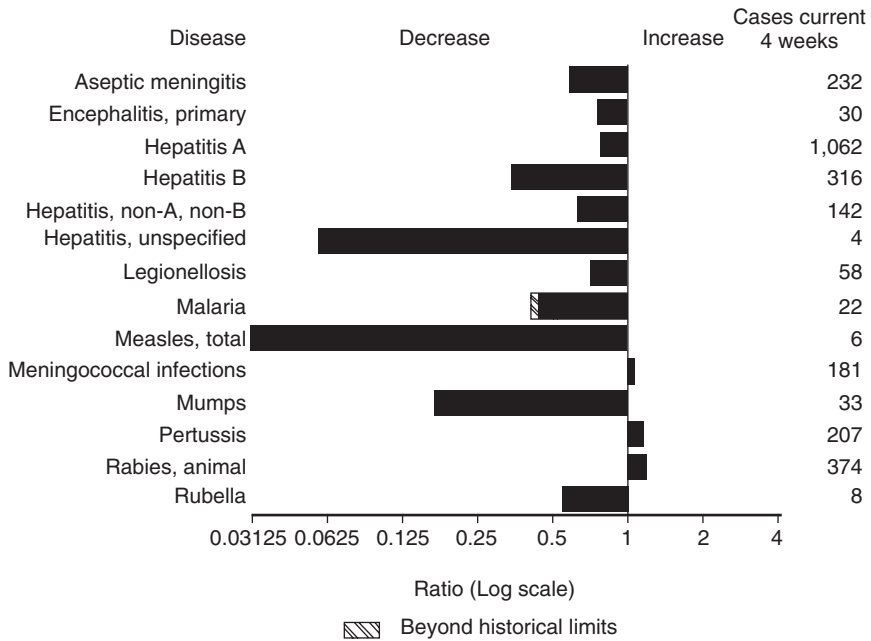


FIGURE 4-3 Notifiable disease reports, comparison of Figure 04-week totals ending February 4, 1995, with historical data—United States.

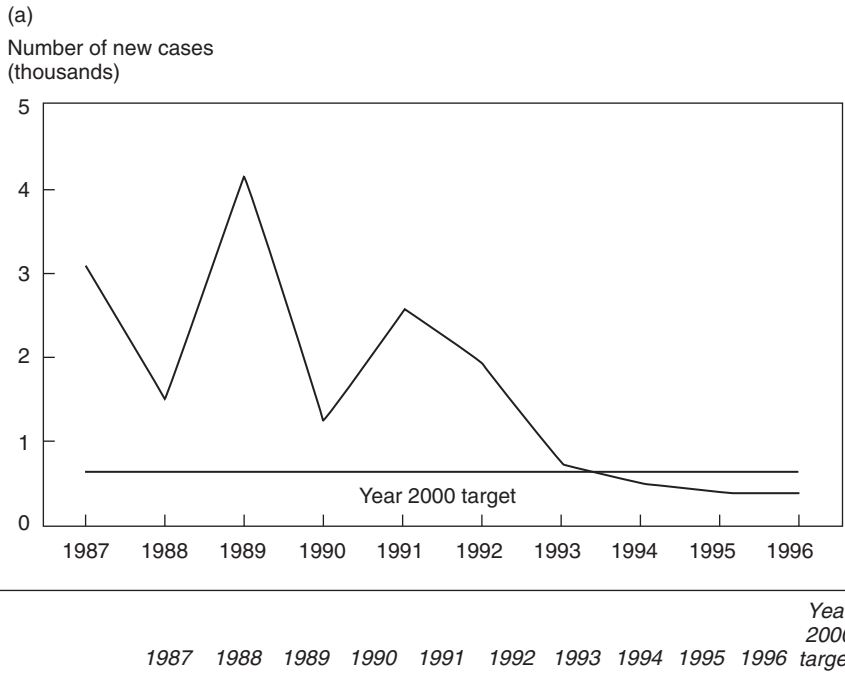
Not Just Counting Cases

Surveillance as a Tool to Describe Risk Groups

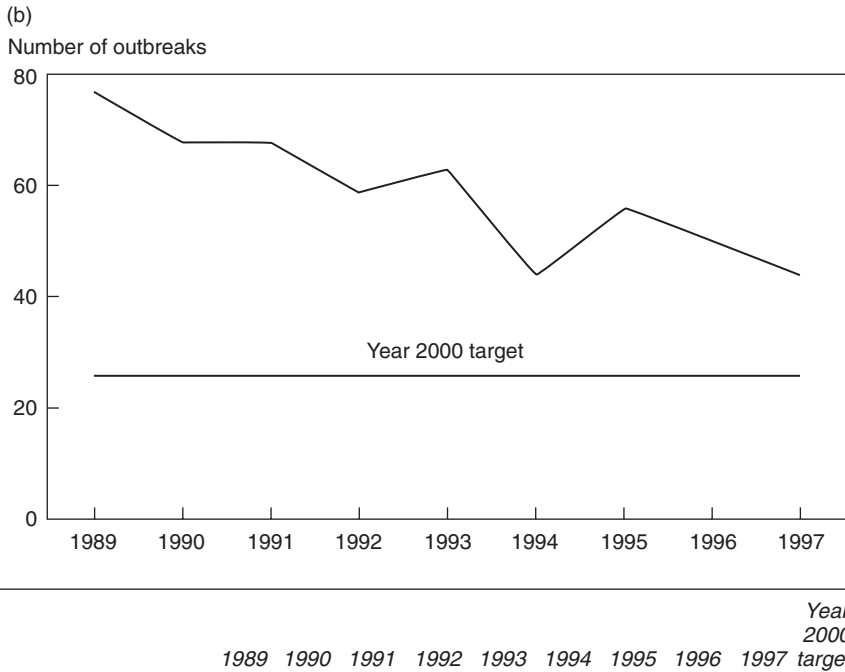
One important purpose of routine, ongoing surveillance of infectious diseases is to gather descriptive data about important health problems. The data reported usually contain demographic data on the cases, such as gender, age, geographic location, and occupation. These data sometimes allow public health programs to be implemented or altered. For example, several decades ago, the case reports of tetanus appeared more often among adult women than in men, especially in female illicit drug users. The data supported the hypothesis that lower-class men were more often immunized upon entry to military service or the workforce or as a result of occupational injuries than were women. These surveillance data led to an effort to immunize women who had previously gone unimmunized.

Prior to the AIDS epidemic, syphilis was most common among men who have sex with men (MSMs); however, a reduction in high-risk sex among MSMs and an increase in risky sex among cocaine users changed the demographics of the disease.¹⁸ In 2005, an increase in syphilis and rectal gonorrhea in men in several cities has signaled a dangerous resumption of high-risk sex among MSMs.

The data available from the routinely reported cases with simple demographic characteristics have often triggered more detailed epidemiologic studies that have led to the design and implementation of prevention strategies. A critical feature of these routine reports is that they are published in the *MMWR* and widely distributed to public health authorities, government officials, news media, and public interest groups. In addition to the nationally



	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Year 2000 target
Occupationally exposed workers. . . .	3090	1520	4189	1258	2576	1923	727	506	407	391	623



	1989	1990	1991	1992	1993	1994	1995	1996	1997	Year 2000 target
All persons	77	68	68	59	63	44	56	50	44	25

FIGURE 4-4 Top, Number of new cases of hepatitis B infections among occupationally exposed workers: United States, 1987–96, and year 2000 target for objective 10.5. Bottom, Outbreaks of infections due to *Salmonella enteritidis*: United States, 1989–97, and year 2000 target for objective 12.2.

distributed *MMWR*, many state and local health departments analyze and publish data about local health problems on a regular basis. For example, in response to the increase in syphilis among MSMs, behavioral researchers studied whether this is due to a decrease in concern about HIV as effective therapies have changed the disease's prognosis or if it is due to exhaustion with practicing safe sex behaviors.¹⁹

Surveillance as a Tool to Evaluate Vaccines

Routine surveillance is often a critical component of the evaluation of vaccines and other public health prevention programs. After a vaccine is licensed, it is important to continue surveillance to measure its effectiveness in controlling the disease in the population and the extent of its use. Prelicensure clinical trials of vaccines cannot take into account the great variety of conditions under which a vaccine might be used or inappropriately used in the field. Outside of the tightly controlled setting of a clinical trial, differences in the disease strain, patient characteristics, vaccine administration, and concomitant medications may all interfere with vaccine efficacy. Several examples of changes in vaccine practices after analysis of postlicensure surveillance data follow.

Modification of Dosing Schedule

The measles vaccine is highly effective for the prevention of measles. Its efficacy is estimated to be 95–97% or higher, when given at 12–15 months of age, after the disappearance of maternal antibodies. However, postlicensure surveillance of children vaccinated at 12 months found somewhat lower vaccine efficacy than when the vaccine was given at 15 months.²⁰ Based on these surveillance data the vaccine recommendations were changed to encourage vaccination at 15 months instead of at 12 months.²¹ After the original licensure of live attenuated measles vaccine in 1963, reported cases of measles declined by over 95%.²² However, reported cases of measles increased in 1979–1980, 1984–1986, and 1989–1991.²² Many of these cases occurred in children who had been appropriately vaccinated. Because measles is highly infectious, it is not possible to establish herd immunity, thus the 2% to 5% of the population who do not respond to the initial measles vaccine are at risk for endemic transmission. The occurrence of measles epidemics in highly vaccinated populations led to the recommendation that a second dose of measles, mumps, and rubella (MMR) vaccine be given at 4–6 years of age.^{23,24} This strategy has further reduced measles incidence. However, imported cases continue to be reported, and indigenous cases, especially among persons who refuse vaccine for religious reasons, are not uncommon.

Modification of Vaccine Components

The importance of postlicensure surveillance to determine vaccine effectiveness in a diverse situation occurred in Brazil when an outbreak of type 3 polio occurred among vaccinees.²⁵ Investigation of this outbreak disclosed that the ratio of types 1, 2, and 3 of 10:1:3 in the vaccine proved to be

inadequately immunogenic for type 3 polio. The trivalent vaccine was then changed to a 10:1:6 mixture, which provided improved immunogenicity for type 3 polio.²⁵

Monitoring Vaccine Administration

During the trial, storage of vaccines usually is optimal. Some live attenuated vaccines require refrigeration and a “cold chain” from the manufacturer to the care setting must be maintained to prevent loss of immunogenicity. However, it is not uncommon for problems with maintenance of a cold chain to impair vaccine effectiveness, especially in tropical, developing country settings. The mode of vaccine delivery can also affect immunogenicity, which may not be realized until postlicensure surveillance. Postlicensure studies of HBV vaccine found unexpected low immunogenicity of the vaccine among those who received the vaccine subcutaneously, rather than by the intramuscular route.²⁶ The trial for intradermally administered rabies vaccine showed sufficient immunogenicity among veterinary medicine students. Based on this, the vaccine was given to Peace Corps volunteers intradermally. The postlicensure evaluation of a rabies death in a vaccinated Peace Corps volunteer in Africa showed that chloroquine, used for malaria prophylaxis, inhibited the immune response to intradermal vaccine.²⁷

Calculating Vaccine Effectiveness

Vaccine effectiveness can be measured epidemiologically by comparing the rates of disease in vaccinees and nonvaccinees. The standard formula for calculating vaccine efficacy (VE) compares the attack rates for disease in the unvaccinated (ARU) with those in the vaccinated (ARV), as follows:

$$VE(\%) = \frac{(ARU - ARV)}{ARU} \times 100$$

The problems in ascertaining cases and assigning vaccine status in a postlicensure study are substantial. Disease manifestation may be altered in vaccinated patients, and care must be taken when developing the case definition to ensure equal ascertainment of cases in the two groups. Even with a highly effective vaccine, cases can occur among vaccinated individuals. If 90% of a population were vaccinated with a vaccine that was 90% effective, only 81% of the population would be immune. Of those not immune, half would have a history of having received vaccine and half would be nonvaccinees. Also, difficulties may exist in determining whether the exposure and risk of disease are comparable in the vaccinated and unvaccinated populations. Variation in the sensitivity and specificity of the case definition and biased case ascertainment that is linked to vaccination status can falsely increase or decrease vaccine efficacy. For example, vaccinated patients may have greater access to health care and may be more likely to be diagnosed as a case than those without access to care, thus falsely decreasing the apparent vaccine efficacy (Table 4-3). The details of measurement of vaccine effectiveness after licensure are covered in greater detail in Chapter 10.

TABLE 4-3 Effects of Different Methodological Problems on Estimation of Vaccine Efficiency

Problem	Likely Effects On		
	ARU	ARV	VE
a. Lack of sensitive definition; equal sensitivity in vaccinees and nonvaccinees; 100% specificity	↓	↓	No change
b. Low-sensitivity definition but more sensitive in nonvaccinees than vaccinees; 100% specificity	↓	↓↓	↑
c. Nonspecific definition; background illnesses are classified as cases; 100% sensitivity	↑↑	↑↑↑	↓
d. Nonspecific definition; low sensitivity	↑	↑↑↑	↓↓↓
e. Cases are classified with knowledge of vaccination status; bias toward detecting cases in unvaccinated and toward failing to detect cases in vaccinated	No change	↓	↑
f. Cases are classified with knowledge of vaccination status; bias toward detecting cases in vaccinated and toward failing to detect cases in unvaccinated	↓	No change	↓

Note: ARU, attack rate in the unvaccinated; ARV, attack rate in the vaccinated; VE, vaccine efficacy.

Source: Reprinted with permission from WA Orenstein, RH Bernier and RR Hinman. Assessing Vaccine Efficacy in the Field: Further Observation. *Epidemiology Rev* 1988;10:212–41.

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Surveillance as a Tool to Eradicate Disease

Smallpox Eradication

After the successful program for the eradication of smallpox, several other infectious diseases were targeted for eradication, including polio, guinea worm, and measles. The smallpox campaign showed that an active and aggressive surveillance program is required. The smallpox eradication program not only relied on reports of smallpox cases to health authorities but actively sought cases by having regular contacts with health care providers, intensive surveillance of villages where cases had occurred, and providing monetary rewards to citizens for reporting confirmed cases.²⁸ This highly active surveillance system was coupled with vaccination of case contacts and preventing their contact with additional susceptible persons during the infectious period. The method became known as the *surveillance and containment strategy*. It replaced the older, ineffective method of attempting to vaccinate 100% of the population.²⁸ Fenner and Henderson detail the small pox control and eradication campaign in their book *Smallpox and its Eradication*.²⁹

The implementation of active surveillance to supplant the passive reporting of cases of smallpox resulted in an apparent large increase in the incidence of cases. This is shown by the surveillance data from the smallpox eradication program in Ethiopia in the 1970s (Figure 4-5). Another issue

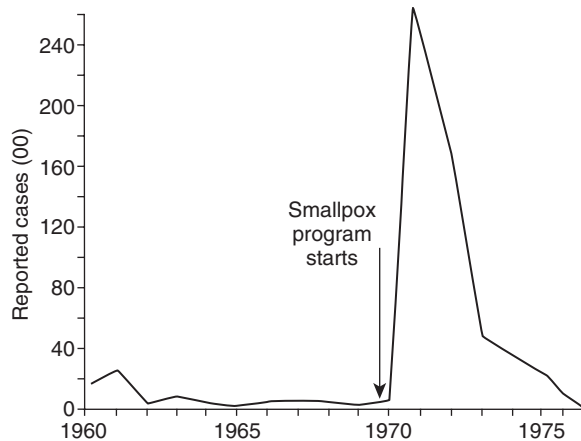


FIGURE 4-5 Evidence of the underreporting of variola minor. Increase in the number of reported cases in Ethiopia following the initiation of intensified surveillance in 1971.

associated with concerted efforts to increase surveillance is that patients with other diseases having similar clinical manifestations may be reported. That is, efforts to increase sensitivity of reporting may lead to decreased specificity, or at least some nonspecificity, of the case reports. In the smallpox eradication program, cases of atypical varicella with clinical features similar to smallpox were commonly reported as possible cases of smallpox.²⁹ In addition, human cases of monkey pox, a newly recognized human infection, were reported, especially in Africans having close contact with monkeys.³⁰ Conversely, cases of monkey pox were underreported, and this disease is more frequently recognized since the eradication of smallpox.³⁰

Poliomyelitis Eradication

Following the successful eradication of smallpox, the Pan American Health Organization (PAHO) in May 1985 proposed a plan to eradicate poliomyelitis from the Western Hemisphere within the next five years.³¹ The proposal was accepted by all PAHO member countries, and a major initiative was launched within months. The program aimed to interrupt the indigenous transmission of wild poliovirus. It relied on the use of trivalent oral polio vaccine given to every child under 5 years of age on national vaccination days, held twice yearly in each country, and on active surveillance for polio cases, especially patients with acute flaccid paralysis. Efforts were made to document each reported case virologically to confirm whether or not the case was due to acute infection with wild poliovirus. A standard benchmark definition of “adequate surveillance” was established that included a very sensitive marker of disease: identification of acute flaccid paralysis (AFP) at a rate of $\geq 1:100,000$ population of children under 5 years old and a very specific marker of disease: two stool cultures for polio virus isolation from

AFP cases taken within 14 days of onset in $\geq 80\%$ of AFP cases. Confirmation of viral etiology was necessary as polio cases declined because, other viral infections, especially enterovirus, cause AFP in at least 1 per 100,000 children child under age 1.

Similar to the smallpox eradication program, extensive active surveillance for cases involving not only health professionals but the general public as well was a central component of the program. However, in the polio eradication program, in contrast to the smallpox eradication program, surveillance was also directed at detecting wild poliovirus in humans and in the environment. In August 1991, the last case of indigenous polio in the Western Hemisphere occurred in a 2-year-old boy in Peru. Three years later, after no additional indigenous cases were detected, despite intensive surveillance, an independent international commission certified to PAHO that polio had been eradicated from the Western Hemisphere.³² While there is considerable hope that polio could be eradicated globally, setbacks in polio control in Nigeria have substantially undermined this campaign.

Surveillance as a Tool to Prevent Disease Spread

Surveillance may also be used to prevent spread of the disease to others. When a patient with active tuberculosis is identified, the report is usually followed by an investigation of the contacts. Any contacts who are infected are given prophylactic therapy. Contact investigation and prophylactic treatment of all contacts is recommended for infectious syphilis, meaning primary or secondary syphilis and meningococcal disease. Surveillance and prevention of nosocomial infections in hospitals and other health care institutions have become integral and critical components of modern health care. These issues are reviewed in detail in Chapter 13.

Specialized Surveillance Programs

There are numerous specialized surveillance programs operating in the United States and globally. These programs address identified needs and are an important part of the public health infrastructure. They also provide useful data for epidemiologic research beyond their primary mission. These are described in greater detail below.

The National Nosocomial Infection Surveillance System

The National Nosocomial Infection Surveillance System (NNIS) began in 1970 when selected US hospitals agreed to report their nosocomial infection surveillance data routinely to a national database maintained by the hospital infection program at CDC. In the 30 years since NNIS was begun, the program has been expanded to include 231 acute care hospitals. Also, considerable attention has been directed to standardization of the definitions for each site of nosocomial infection and requirements for adequate personnel and laboratory resources for the diagnosis of nosocomial infections to ensure that the data are reasonably accurate and comparable among different hospitals.

The objectives of NNIS are the following:

1. Estimate the extent and nature of nosocomial infections in the United States.
2. Identify changes in the incidence of nosocomial infections and the pathogens that cause them.
3. Provide hospitals with comparative data on nosocomial infection rates.
4. Develop efficient and effective data collection management and analysis methods.
5. Conduct collaborative research studies of nosocomial infections.

Epidemiologists from the hospital infection program at CDC frequently assist hospitals, both those participating in NNIS and others, in the investigation and control of nosocomial outbreaks.

Nosocomial infections are a very important health problem in the United States, and antibiotic-resistant organisms often may be selected for and transmitted in this setting. It has been estimated that over 2 million patients develop a nosocomial infection in the United States each year, at a cost of approximately \$3.5 billion. The NNIS is the only ongoing surveillance program of nosocomial infections in acute care hospitals in the United States. Data from the NNIS program are described in detail in Chapter 14.

Emerging Infections

Recently, considerable attention has been directed at emerging and reemerging infections. This topic is covered in detail in Chapter 13 of this book. A sensitive system of surveillance for the early detection of emerging infections is a critically important component of the public health response to this problem.

The Institute of Medicine of the National Academy of Sciences reviewed the problem of emerging infectious diseases in 1991.³³ This expert committee recommended that the CDC develop a strategy for improved early detection and response to the threat of emerging infections. The CDC established an emerging infections program (EIP) in seven states: California, Connecticut, Georgia, New York, Maryland, Minnesota, and Oregon. The goals of the EIP are to improve national surveillance for new and emerging infectious diseases, conduct applied epidemiologic and laboratory research, develop prevention and control measures, and strengthen the national public health infrastructure.

To further these goals, the CDC granted a Cooperative Agreement Program Award to the Infectious Diseases Society of America (IDSA) in 1995. The main objective of the award was for IDSA to establish a provider-based emerging infections sentinel network. The Emerging Infections Network (EIN) currently includes over 900 infectious disease (ID) member specialists worldwide. The EIN members serve as field officers to identify new and unusual clinical events. Because of their professional experiences, EIN members can link to the broader community of ID specialists—local, national, and global public health practitioners—to tap into their collective resources and research knowledge. The EIN members communicate electronically via a listserv. The listserv acts as an informal mechanism for the flow of information, as well as a venue for administration of formal, either urgent or periodic, surveys.

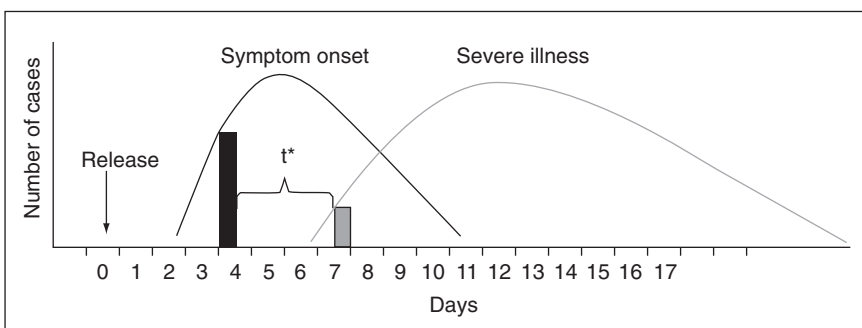
Outbreak investigations merit urgent queries; whereas, periodic surveys of the membership evaluate ongoing public health needs in the field. The EIN contributes annually to tracking of influenza and availability of vaccines and has participated in information gathering relating to diseases such as West Nile virus encephalitis, smallpox vaccination, *Clostridium difficile*-associated disease, and severe acute respiratory syndrome (SARS).

Syndromic Surveillance

The terrorist attacks of September 11, 2001, and the subsequent anthrax outbreak emphasized the need for the development of a system that would enhance the US terrorism preparedness. The main goal of such a surveillance system is the early detection of outbreaks caused by intentional emergence of biologic and chemical agents.³⁴ Clusters of human illness need to be quickly identified and described in an accelerated fashion due to the nature and scope of the threat and the imperative to limit human casualties.

The resulted innovation is the development of *syndromic surveillance*. The CDC defines syndromic surveillance as “an investigational approach where health department staff, assisted by automated data acquisition and generation of statistical alerts, monitor disease indicators in real-time or near real-time to detect outbreaks of disease earlier than would otherwise be possible with traditional public health methods.”³⁵ The fundamental premise of syndromic surveillance is that in order to identify disease clusters early, potential cases of a biological or chemical outbreak are defined by virtue of their symptoms and before their clinical or laboratory confirmation and reporting via traditional surveillance channels. Figure 4-6 provides a graphic representation³⁶ of the lead time allowed by detection of early symptoms, as opposed to clinical disease manifestation, thus allowing public health officials time for a rapid response in limiting the outbreak.

Standardization of syndromic surveillance protocols remains a complex and unresolved issue. Despite deployment of different systems by numerous local and regional jurisdictions following the anthrax outbreaks of 2001, implementation challenges remain. Statistical signaling of an unexpected disease cluster is very difficult because of limitations on the knowledge of



* t = time between detection by syndromic (prediagnostic) surveillance and detection by traditional (diagnosis-based) surveillance.

8 FIGURE 4-6 Syndromic Surveillance—Rationale for Early detection.

strong correlations between nonspecific symptoms and disease, the relative inexperience of clinical and public health respondents with biologic and chemical agents, and the wide array of data sources, such as emergency department patient volume aberrations, poison control center calls, medical examiner data, medication sales, and Internet-based health-related inquiries by the public. Further research is needed to define optimal data sources, evaluate syndromic definitions, standardize signal-detection methods, incorporate information from existing surveillance systems, and develop response protocols.³⁶

In addition to syndromic surveillance, the CDC already had in place several specific programs to monitor intentional and unintentional epidemics. These include the FoodNet, PulseNet, ArboNet, and tuberculosis programs.

FoodNet and PulseNet

The Food-Borne Diseases Active Surveillance Network (FoodNet) is the food-borne disease component of CDC's EIP. FoodNet is a collaborative project among CDC, the seven EIP sites, the US Department of Agriculture (USDA), and the US Food and Drug Administration (FDA). It consists of active surveillance for food-borne diseases and related epidemiologic studies designed to help improve public health officials' understanding of the epidemiology of food-borne disease in the United States. The total population included in the special surveillance efforts of the FoodNet catchment areas is 20.3 million people, or 8% of the population of the United States. FoodNet provides a network for responding to new and emerging food-borne diseases of national importance, monitoring the burden of food-borne diseases, and identifying the source of specific food-borne diseases.

The program includes surveillance of several populations, including the following:

- Active laboratory-based surveillance
- Survey of clinical laboratories
- Survey of physicians
- Survey of the population
- Case-control studies

Closely linked to FoodNet is another laboratory-based program called PulseNet. PulseNet is a national network of public health laboratories that performs DNA fingerprinting of bacteria that might be the cause of food-borne illnesses. The network permits rapid comparison of the DNA fingerprint patterns through an electronic database at the CDC. The DNA fingerprinting method used is pulsed-field gel electrophoresis (PFGE). The PFGE methods are described in some detail in Chapter 8. The data from FoodNet and PulseNet allow a better understanding of the epidemiology of food-borne diseases of national significance.

ArboNET

The first domestically acquired cases of West Nile virus (WNV) encephalitis were described in the United States in the summer of 1999.³⁷⁻⁴² By 2002, the WNV epidemic had spread to 44 states, the District of Columbia, and

Canada, making it the largest documented WNV epidemic in the Western Hemisphere. To assist in the development of WNV surveillance and response, the CDC implemented an electronic-based surveillance and reporting system, ArboNET, to track WNV infection. Although state jurisdictions may employ varied surveillance systems, the CDC is coordinating the reporting of WNV infection data in humans, other mammals, birds, and mosquitoes to the national ArboNET system in a standardized format and schedule.

The objectives of this system are to monitor the geographic and temporal spread of WNV in the United States; to develop national public health strategies for WNV surveillance, prevention, and control; to develop a more complete regional picture of the distribution and incidence of the other clinically important arboviruses (e.g., eastern and western equine encephalitis, St. Louis encephalitis, La Crosse, Powassan) in the United States; to provide national and regional information to public health and government officials and the general public; and to evaluate the need for additional resources.⁴³

ArboNET reporting incorporates data from sentinel surveillance of avian, equine, and mosquito morbidity and mortality as indicators for epizootic activity and human risk, as well as surveillance of human syndromes (i.e., encephalitis cases), diagnostic tests of antibody specimens, physician surveys, and specific research projects, such as case-control studies. Information technology advancements allow for ArboNET to be readily accessible by local jurisdictions for data entry and verification in real time, thus facilitating WNV monitoring. This electronic-based system enables a multidisciplinary team of public health and agriculture officials to assess WNV epidemic implications and coordinate the local and national WNV response with effective allocation of resources.

Tuberculosis Surveillance

Enhanced tuberculosis surveillance was established as part of the CDC's EIP in response to the reemergence of tuberculosis in the United States caused by the neglect of tuberculosis in the decades prior to the AIDS epidemic and then the resurgence of TB in populations at with or at risk for HIV/AIDS. The reinvigorated programs have included increased funding to health departments for more active case detection, directly observed therapy (termed *DOTS*) of active cases with effective drug combinations and molecular characterization of all isolates from patients in the seven EIP states. These molecular epidemiologic studies of isolates from patients with recent tuberculosis have led to a reassessment of the proportion of cases in adults that are due to reactivation versus recent tuberculosis. Studies from several locations have suggested that recent infections in adults are more common than had been previously believed, accounting for about 35% of active cases in some areas.⁴⁴ Also, several clusters of tuberculosis cases acquired by casual contact and unusual exposures, such as bronchoscopy, have been documented.⁴⁵ These issues are reviewed in greater detail in Chapter ••.

9 10

Influenza Surveillance

Influenza has probably received more systematic global surveillance than any other disease in the last several decades. Active surveillance of influenza is

necessary to monitor the emergence of new influenza viruses that arise by genetic drift or reassortment (genetic shift). The detection of new influenza viruses on a global basis is required to have sufficient lead time to produce and distribute new influenza vaccines. Because of the great genetic variability of influenza viruses, the vaccine must be reformulated on an annual basis. The World Health Organization (WHO) has established a global network of influenza surveillance laboratories, where isolates from infected persons are characterized serologically and genetically. Each year, a panel of experts meets and makes a prediction as to which of the circulating viruses is most likely to be responsible for an epidemic during the ensuing influenza season. Vaccine preparation for the next year is based on this recommendation (see Chapter ●●).

11 12

In addition to this program of global influenza surveillance, the CDC maintains an influenza surveillance program in the United States. This program, which is described in more detail in Chapter 17, monitors influenza and pneumonia deaths in adults in 121 US cities. Also, special influenza surveillance programs include monitoring visits to sentinel physicians and hospital emergency rooms, as well as obtaining data concerning hospital admissions and school absenteeism in selected populations. For several years, Baylor University in Houston, Texas, has maintained comprehensive community-wide surveillance of influenza in Harris County, Texas, with funding from the National Institutes of Health (NIH) to evaluate the influenza morbidity and mortality at the population level.⁴⁶

Hepatitis Surveillance

The hepatitis program at CDC has established the Sentinel County Study, a collaborative network of county health departments for the purpose of monitoring the epidemiology of viral hepatitis. This program has been in operation since 1982. The counties involved in this surveillance program are provided with personnel to do active surveillance of hepatitis occurring in residents of these sentinel counties. This surveillance includes maintaining regular active contact with physicians, other health care providers, and laboratories to detect all cases of hepatitis. Each hepatitis case is interviewed to determine risk factors, and laboratory evaluation is done to establish the hepatitis virus type. The data from the Sentinel County Study have been of considerable value in monitoring the incidence, temporal trends, and risk factors for infection with the different hepatitis viruses in the United States. Although viral hepatitis is one of the reportable diseases in the United States, the reporting is incomplete, and the passively reported data do not provide reliable estimates of the type of hepatitis or the risk factors for infection. The epidemiology of viral hepatitis and the data from the Sentinel County Study are reviewed in more detail in the chapter on hepatitis (Chapter ●●).

13 14

Vaccine Adverse Event Reporting System

The National Childhood Vaccine Injury Act of 1986 mandated the reporting of certain adverse events following vaccination to help ensure the safety of vaccines distributed in the United States. This act led to the establishment of the Vaccine Adverse Event Reporting System (VAERS) in November

1990. The program is operated jointly by the CDC and FDA. VAERS receives about 800–1000 reports each month from health care providers, vaccine manufacturers, and vaccine recipients or their parents or guardians. One of the dilemmas in public health is the imbalance between the tremendous benefits from vaccines during the 1900s in reducing morbidity and mortality and the high degree of suspicion that the public has about the dangers of new vaccines or vaccines in general. This has led to reluctance to develop, test, and license new vaccines among some pharmaceutical firms, due to concerns about litigation, as vaccines are blamed for health events that are merely coincidental. This situation, which is inimical to further advances in public health, has been addressed in part by the VAERS surveillance program. Although VAERS is a passive reporting system and does not include denominator data, it identified an uncommon complication of the rotavirus vaccine. On further study, intussusception was attributed to 1 in 5000–10,000 vaccine recipients.⁴⁷

In 1991, the CDC, in collaboration with several large health maintenance organizations (HMOs), established another surveillance system to monitor adverse reaction to vaccines. This program is called the Vaccine Safety Datalink Project (VSD).⁴⁸ The VSD project contains a large database of vaccinated children and adults where adverse events can be linked to denominator data on the number of vaccines administered.

Because the HMO populations included in the VSD project are relatively stable and receive all of their health care through the HMO, these data are less subject to bias than the VAERS passive reporting systems.

Other Surveillance Data

There are several surveillance systems in the United States that have been established to obtain data for other purposes that could be utilized to evaluate infectious diseases issues. Among these are the Surveillance, Epidemiology, and End Results (SEER) project of the National Cancer Institute and the National Health and Nutrition Assessment Study (NHANES) of the National Center for Health Statistics.

SEER Study

The SEER project of the National Cancer Institute of NIH includes cancer registries in 11 geographic areas, including 6 states, 1 territory, and 4 metropolitan areas. Through contacts with hospitals and pathologists, the occurrence of incident cases of cancer are monitored, and ascertainment is believed to be very complete. Data collected on cancer patients include demographic characteristics; exposures, such as industrial or occupational histories; characteristics of the cancer (site, morphology, stage); treatment; and outcomes. These patients have been enrolled in a number of studies. They are a useful population for the study of infectious causes of cancer, such as hepatitis B virus (HBV), hepatitis C virus (HCV), *Helicobacter pylori*, human papillomavirus (HPV), Epstein-Barr virus, and other infections.

National Health and Nutrition Survey

The NHANES involves a random sample of the US population, which is done about every 10 years to evaluate the prevalence of health conditions and the nutritional status of the US population. Randomly selected subjects are asked to participate in a survey that includes a detailed assessment of health conditions and disabilities, a physical examination, and collection of blood specimens. The blood specimens are evaluated for several biochemical and nutritional components, and a repository is created. Several studies of infectious diseases have been evaluated using the repository and questionnaire data, including the prevalence of infection with HBV, HCV, and herpes simplex viruses types 1 and 2. These data are discussed in Chapters 22 and 23.

Behavioral Surveillance

The Behavioral Risk Factor Surveillance System is an ongoing telephone survey that is conducted by over 40 state health departments in the United States. The survey includes standardized questions on various risk factors for disease, including cigarette smoking, alcohol use, seat belt use, and exercise. These data are analyzed and published by the CDC and are very useful in evaluating temporal trends in health risk behaviors. Additional questions are added periodically.

Another example of an active behavioral surveillance effort is the national HIV Behavioral Surveillance (NHBS), which began in 2004 and is funded by CDC. NHBS is an anonymous, community-based survey of populations, such as men who have sex with men (MSM), injection drug users (IDU), and high-risk heterosexuals, who are at an elevated risk for the acquisition of the HIV virus. A standardized behavioral questionnaire is administered in 25 metropolitan areas around the United States on an annual basis to individuals of the aforementioned HIV-risk groups. These individuals are actively recruited using generalizable sampling methods. Data from NHBS is used to assess the prevalence of HIV-related risk behaviors, ascertain changes over time in the prevalence of these behaviors, and enlighten city and state health departments as to the local needs for HIV prevention resource allocation.

Drug Abuse Warning Network

The Drug Abuse Warning Network (DAWN) collects data on morbidity and mortality related to illicit drug use from hospital emergency departments and medical examiners or coroners' offices in 27 metropolitan areas. It is a useful source of data on the types of illicit drugs in common use in a geographic area and the associated health problems associated with their use. The DAWN data have been useful in detecting changing types of drug use that have adverse health consequences. The DAWN study is especially useful for detecting changes in the rates of drug overdose.

International Surveillance Systems

In addition to the numerous sources of data on health events in the United States listed above, there are various sources of international surveillance

data. Most national governments have established surveillance programs on cancer and infectious diseases. Some of those data are published in the *Weekly Epidemiologic Record* of the WHO. Also, the International Union Against Tuberculosis and the International Cancer Control Organization in Lyon, France, collect and publish data on tuberculosis and cancer, respectively.

The importance and effectiveness of international surveillance of infectious diseases coordinated by the World Health Organization was demonstrated during the global SARS outbreak in 2003. Reports of SARS cases were made to the WHO Global Outbreak Alert & Response Network (GOARN), and the response to the disease was coordinated through the Global Public Health Intelligence Network (GPHIN) of WHO. This coordinated response permitted the identification of a novel coronavirus (SARS-Co-V) as the etiologic agent. This in turn informed control strategies within a few weeks of the recognition of the epidemic. The WHO is building on their successful response to the global SARS epidemic with improved surveillance and response using an available field team of epidemiologists and coordinating with other international health agencies, such as CDC and Medicine Sans Frontiers (MSF).

Other Surveillance Issues

Confidentiality of Data

For many diseases, it is of critical importance to maintain the confidentiality of surveillance data. For some conditions, such as HIV/AIDS, the issues of confidentiality are critical and must be considered in order to obtain valid data and to prevent harm to the persons surveyed. The issue of confidentiality arose over a plan to test sera from NHANES participants for HIV antibodies. After the plan was proposed initially, it was dropped because of fears that testing the sera for HIV would substantially reduce the participation rate and the representativeness of the sampled population if counseling and informed consent were required of the subjects studied. If only persons at low risk to HIV participated in NHANES, it would not only compromise the validity of the HIV prevalence estimate but of other health conditions measured in NHANES, as well. Eventually an anonymous, random survey of HIV prevalence in the general population was done by the NCHS.⁴⁹

One method of dealing with this ethical and scientific dilemma is to use blinded, anonymous serologic surveys to estimate the prevalence of disease in critical populations. In blinded surveys, serologic testing can be performed on sera remaining after a clinically indicated test is completed and patient identifiers have been removed. Because the specimens are not linked to any personal identifiers, informed consent is not required. Ideally, the sera are available from an unbiased sample of a population. Examples of unbiased specimens include mandated programs such as infant screening programs for lead, phenylketonuria (PKU), hypothyroidism, and glucose-6-phosphate deficiency, or syphilis screening of persons attending sexually transmitted disease clinics. In hospitals, it is also possible to sample from the many clinical specimens collected to generate unbiased samples of the patient population. This method was used, originally in Massachusetts but later across

the entire United States, to determine the prevalence of HIV in pregnant women.⁵⁰ Maternal antibodies are passively transferred to the infant during pregnancy so that HIV serology tests of blood collected from the infant at birth are a reflection of the maternal HIV status, not the infant's. The results from the infant blinded screening surveys provided valid and valuable public health data on the prevalence of HIV early in the US epidemic. These surveys receive considerable negative political attention as concerns were raised that all pregnant women should be required to have an HIV test to protect the infant from HIV. Rather than transform the program from blinded serosurveys to mandatory testing, which many public health officials feared would destroy the unbiased nature of the surveys and drive at-risk mothers away from health care, the CDC ended the maternal surveys. Despite the end of the maternal surveys, blinded anonymous surveillance of HIV seroprevalence in other populations continued and has been extremely important in tracking the US epidemic.⁵¹

Particularly as HIV testing is voluntary, making it inherently biased, and it was not a reportable disease early in the epidemic. Blinded serosurveys are not only used for diseases with confidentiality issues such as HIV but may also be applied to any infection where laboratory identification is possible.

Conclusion

Whether it is to define the burden of disease in a population to inform policy makers and caregivers, to evaluate the success of vaccine or other prevention programs, to monitor intentional or unintentional emerging diseases, or to provide insight into underlying health and risk behaviors in a population, surveillance is one of the cornerstones of public health.

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