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Surveillance of Disease: Overview

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Historical Development

'Surveillance' is derived from the French phrase for 'watching over' ('sur' means 'from above' 'veiller' means 'to watch'). In civil society, the police and governmental surveillance systems monitor the behavior, activities, and other changing information of people and are on the alert for abnormal incidents that may cause hazards in communities, nationally and internationally. The information gathered by surveillance is shared with authorities responsible for setting up measures to eliminate the cause of the hazard and protect communities. On the other hand, the human body provides immunological surveillance by setting up systems that monitor for and recognize foreign materials and malignant cells which are presented to the body's immunological mechanisms for destruction.

Public health surveillance as defined by the Centers for Disease Control and Prevention (CDC) is "the ongoing systematic collection, analysis, and interpretation of outcome-specific data for use in the planning, implementation, and evaluation of public health practice." In the early twentieth century, information gathering on infectious diseases and other hazards to humans was developed in parallel with the development of microbiological technology and epidemiology. Data collected were analyzed and the results distributed to systems and individuals responsible for control actions. Epidemiological surveillance marked the beginning of a new era for the prevention and control of infectious diseases. Surveillance activities have since been expanded from infectious diseases to chronic diseases and injuries. In addition, the systematic and long-term collection of vital statistics and health-related social and economic indicators also contribute to disease surveillance. In this article, we discuss the major disease surveillance systems and public health prevention and control activities.

Around the middle of the twentieth century when infectious diseases were a major problem and menace to public health, two medical experts attempted to introduce surveillance as an essential component of public health practice. Alexander Langmuir, then Chief Epidemiologist at the Centers for Disease Control and Prevention (then Communicable Disease Center), developed the framework for the systematic surveillance of infectious diseases and the associated control programs. In 1963, Langmuir defined surveillance as (1) systematic and active collection of pertinent data of target disease(s); (2) assessment and practical report of these data; and (3) the timely dispatch of such reports to individuals responsible for formulation of action plans. It is important to note that surveillance would not be useful unless the data collected translates to information that is made known and acted upon by individuals responsible for initiating action plans ('surveillance for action'). In principle, a surveillance system does not include the control measures. A surveillance system is better if it is independent of the control system.

Experience has shown that, on some occasions, disease prevalence was artificially modified by individuals who were responsible for control measures and who sought to obtain seemingly better results than what actually occurred. In the 1960s, Karel Raska, the Director of the Division of Communicable Diseases at the World Health Organization (WHO), further expanded the definition of surveillance to include epidemiological research in surveillance activities. To promote research in surveillance, Raska approved special funds for research into strengthening the surveillance system for the newly intensified smallpox eradication program in 1967. Malaria surveillance was similarly enhanced after epidemiological research comparing the prevalence of malaria in individuals using and not using mosquito nets demonstrated the effectiveness of malaria control with mosquito nets.

In the area of public health practice, we may need to rethink the boundary of surveillance. It may be prudent not to expand it to encompass broad epidemiological research that may be of interest to researchers and health officers, but may not lead to practical public health actions that reduce the immediate hazard or risk. Hence, the use of surveillance as a tool for public health action may need to be further refined and consolidated.

The latest challenge in surveillance has been in bioterrorism, with the recent attacks using anthrax as the bio-weapon in Chile and the United States in 2001. Surveillance of bioterrorism agents, such as *Bacillus anthracis*, *Clostridium botulinum*, and the smallpox virus, is actively carried out by many developed countries.

Surveillance Methods

Target Disease

The target diseases for surveillance are key to defining the sensitivity, specificity, effectiveness, and efficiency of the surveillance systems used. Febrile rash illnesses caused by infections such as measles and chicken pox, and neurologic diseases such as poliomyelitis and meningococcal meningitis may be detected or suspected rapidly by surveillance systems and allied workers. Identification of legally reportable infectious diseases requires clinical and laboratory confirmation by experience health-care workers. Certain principles underlie the identification of target diseases.

Surveillance systems usually target a particular disease or a limited number of diseases. Disease surveillance officers should have a clear idea of the clinical presentation, mode of transmission, and infectivity of the disease. Furthermore, it is important for surveillance officers to have knowledge of the probable frequency or incidence of such diseases, and the attitudes and practices of the at-risk populations toward the diseases. While some populations may be less forthcoming

with the disease status of individuals, others may be happy to collaborate with surveillance efforts and willingly report incidence of the target diseases. Surveillance of target diseases can sometimes take the form of reporting of symptoms or syndromes, such as jaundice surveillance for acute hepatitis B and acute flaccid paralysis (AFP) for poliomyelitis. Further confirmation of the diseases is carried out, after the symptom or syndromic reporting.

The Surveillance System

The surveillance system is usually set up as a distinct section or organization within the national or regional health system and has an independent function as discussed in the previous section.

Community-Based Surveillance

The main reporters are villagers or town inhabitants or health workers in the dispensary or clinic managing patients with the target diseases. Public campaigns through the mass media via the radio, television, and the press were crucial to encourage disease reporting to the nearest health center or designated office in the village, which will forward the information to relevant health authorities (Figure 1).

Clinic- and Hospital-Based Surveillance

The main reporters are physicians who manage the patients and diagnose the target diseases. This surveillance system functions in tandem with the community-based surveillance and is critical for identifying rare diseases and diseases that are difficult to be identified by the community. The advantage of this system is the completeness of the surveillance coverage, if clinics and hospitals are fully compliant with the notification of target diseases. Needless to say, the clinic or hospital administration should be fully informed and understand the importance of such a surveillance system.

Nosocomial or health care–associated infection is a special surveillance target in health-care settings and should be managed by a specially appointed committee. The hospital administration should be regularly updated on the incidence of nosocomial infections and take measures to prevent and control them.

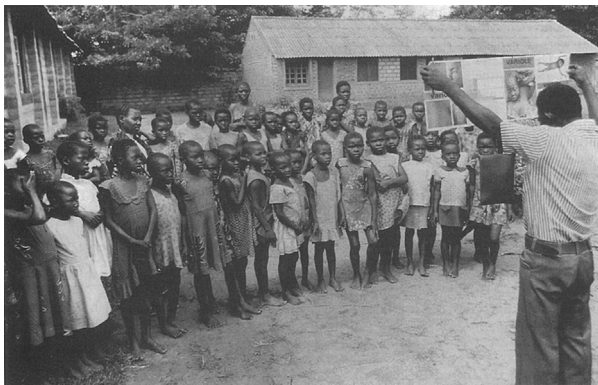


Figure 1 Community-based surveillance needs to be understood by the community. A surveillance information officer is explaining the disease and why it should be reported.

Active or Passive Surveillance

Community- and hospital-based surveillance involving reporting by the public and health-care professionals constitutes passive surveillance. For nontarget diseases that are not in the routine reporting system and for urgent surveillance reports, active surveillance may be required. This often involves the formation of special teams who make house-to-house or clinic-to-clinic or hospital-to-hospital visits to determine the incidence of an emerging disease either through direct communication with members of the community or health-care staff or through review of clinical records or sick individuals on site.

Special Surveillance

In addition to the conventional surveillance systems, innovative solutions may sometimes be necessary to enhance the sensitivity and effectiveness of existing systems.

Rewards

The effectiveness of surveillance often depends on the public's interest in reporting a disease. Reward is, in certain circumstances, a useful tool for the public health authorities to express the importance of reporting to the public. For example, a reward system was utilized to encourage reporting in many countries such as India and Somalia during the smallpox eradication program (1967–80). In 1978, when the world's last probable smallpox case was discovered in Africa, the WHO offered a reward of US\$1000 to encourage reporting of active smallpox (Figure 2). The announcement led to many smallpox cases being reported from West Africa, Indonesia, and even Heathrow and Kennedy airports. All reports were investigated by the WHO and subsequently confirmed to be negative by laboratory tests.

Zero Reporting

The surveillance system will almost certainly receive positive reports of diseases of interest when identified. However, when the system does not receive any report of cases, it cannot distinguish between 'no case detected' and 'failure to report.' Zero reporting removes this uncertainty and provides the assurance that the disease did not occur during a specified time period of reporting such as 1 week or month. Regular zero reporting is an indicator of the sensitivity of a surveillance system. Zero reporting is useful for close surveillance of infections with pandemic potential (such as influenza) for dangerous pathogens that require immediate public health actions in high-risk areas and for diseases that are targeted for eradication such as poliomyelitis. The WHO requires monthly reporting of AFP cases even if there are no cases ('zero reporting'), to enhance the sensitivity of global AFP surveillance.

Handling Inaccurate and Incomplete Surveillance Reports

Inaccurate and incomplete surveillance reports are the result of the incompetence of technical personnel, active concealment of



Figure 2 WHO's poster in mid-1978, publishing the reward of US\$1000 for finding a case of smallpox.

disease occurrence, or the combination of these two factors. Although the inaccuracy and incompleteness of reporting may occur sporadically, they have considerable influence on the success of control measures which require high-quality surveillance data.

If such incomplete surveillance reports were made intentionally by health authorities, the consequences may be disastrous. Examples include the smallpox epidemic in the Horn of Africa during the last phase of the global smallpox eradication program in 1976–77 and the early phase of the epidemics of the severe acute respiratory syndrome (SARS) in East Asia which resulted in transmission to other continents. How should inaccurate and incomplete surveillance reports be managed? There has been no standard solution thus far, but attempts to address such practices include practical dialogue, development of collaborative research, use of political pressure and recommendations from higher authorities, and emphasis on moral obligation. Experience has shown that inaccurate and incomplete reporting from affected areas has often resulted in disastrous outcomes from the failure of disease control due to late recognition of the epidemic.

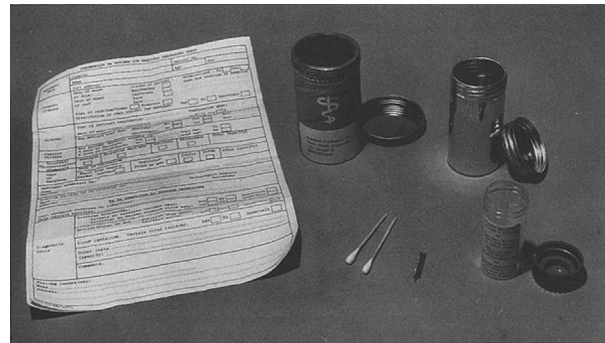


Figure 3 Surveillance of specific diseases: container used for smallpox specimen. Transportation of dangerous pathogens or specimens requires special double container to ensure safety.

Laboratory Diagnosis and Surveillance System

Surveillance requires the collaboration of laboratories to confirm the diagnosis if initial reports are based on clinical diagnosis alone. However, a laboratory diagnosis may not be necessary in some situations. For example, if there is a large number of cases with similar clinical manifestations, laboratory testing of only cases that are representative of the outbreak may be adequate, provided that missing the correct diagnosis of the other cases does not pose significant risk in developing the control measures. This may be applicable to the determination of vaccination use for the containment of outbreaks of measles, hepatitis A, and so on.

When determining the type of test (antigen or antibody test, viral/bacterial isolation, polymerase chain reaction (PCR) test, etc.) to be used for surveillance, the turnaround time for the test results is a key consideration. The reliability of the testing technique is another important factor and quality assurance with regular assessment of the laboratory processes and reagents, and periodic validation of the results by a reference laboratory is absolutely essential.

For vertical disease-specific surveillance programs such as the poliomyelitis, measles, and human and avian influenza, the WHO has designated reference laboratories and collaborating centers for global laboratory surveillance. As and when the need arises, national reference laboratories can also be established by individual countries. **Figure 3** shows the special collection kits that were used for the safe and easy handling of specimens during the WHO smallpox eradication program (1967–80). During that time, countries which did not have the appropriate laboratory facilities for smallpox testing were assisted by reference laboratories in neighboring countries through coordination by the WHO. Additional safety precautions and measures were taken for the handling and transportation of such highly infectious specimens (**Figure 4**).

Analyzing Surveillance Data

Surveillance data collated from the various sources (community, clinic, and hospital) can be described in terms of time, place, and person – the key elements of descriptive epidemiology.

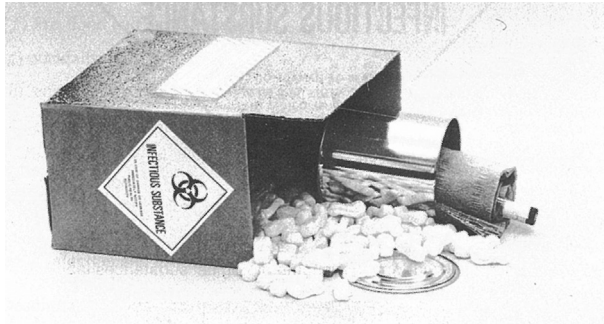


Figure 4 Example of packaging of an infectious substance. Note infectious substance label on the box.

Time

The dates of the illness onset and specimen collection are crucial time points in the clinical course of the disease. A line listing of sick individuals with the respective dates is very useful for compilation of the number of disease incidence by the week or month. The WHO Weekly Epidemiological Record (WER) and the CDC Morbidity and Mortality Weekly Report (MMWR) report disease incidence by the epidemiological week. By convention, the date of the illness onset is the date used for disease surveillance and for plotting an epidemic curve for monitoring an outbreak. However, when the date of illness onset is not available, the date of reporting is often used instead (Figure 5). Sometimes, other dates such as the date of receipt of disease notification from respective health centers is recorded and monitored to assess for the timeliness of the surveillance system in certain rural areas.

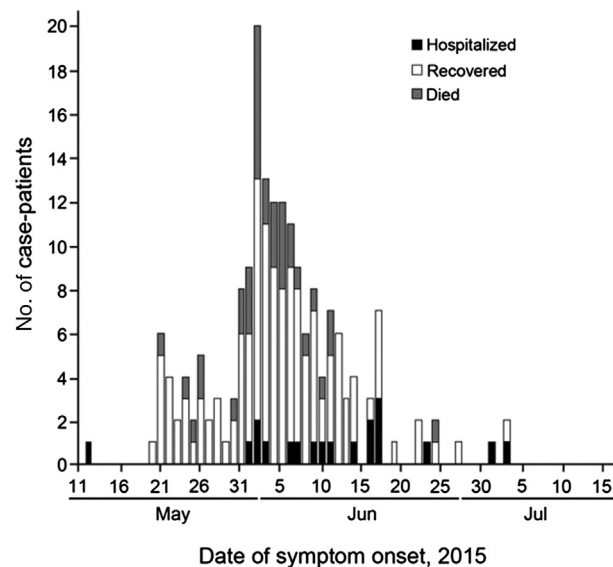


Figure 5 Middle East respiratory syndrome patients in South Korea, as of 15 July 2015. When date of illness onset was unavailable, date of reporting was used. Reproduced from November 2015. *Emerg. Infect. Dis.* 21 (11), 2088–2090.

Place

Documenting the geographical areas and distribution where the disease has occurred and is occurring is important to assess for the spread of the disease. The places visited by the infected individual prior to the illness onset is important for determining the source of the infection, while the movement of the infected individual during the course of the illness is crucial for contact tracing to limit the spread of the disease. In today's highly connected world, air travel has hastened the transmission of infections across continents, as we have experienced during the SARS epidemic in 2002–03, the pandemic influenza A(H1N1) in 2009, the Ebola virus disease (EVD) epidemic in 2014, and the Middle East respiratory syndrome coronavirus (MERS-CoV) epidemic in 2012–15 (Figure 6).

Person

In addition to time and place, data on individual infected persons including sociodemographic details, such as age, gender, ethnicity, occupation, are also essential information to be collated and analyzed. Along with the movement history and information on the places visited by the infected individual, the activities engaged by the individual and animals or persons that the individual contacted with during the incubation period of the disease should be assessed.

The descriptive analysis of surveillance data in terms of time, place, and person will provide important information to guide disease prevention and control efforts. As surveillance is for action, the information should be shared with individuals who are responsible for disease prevention strategies and control plans. Further analytic epidemiology will assess for and identify risk factors associated with the disease or mortality from the disease, and enable health officials to better target public health prevention and control activities.

Salient Surveillance Experiences

Sentinel Surveillance

Sentinel-based surveillance may help to improve weaknesses in target disease surveillance programs by closely monitoring the situation in a specified area. For example, global surveillance on certain diseases may have information gaps due to political unrest, disinterest, poorly developed infrastructure, etc., and to address this, the Agency for Cooperation in International Health (ACIH), a Japanese nongovernmental organization, has developed a voluntary sentinel surveillance system involving 59 sentinel sites in 32 countries in South America, Africa, and Asia for selected target diseases including cholera, measles, and dengue fever (Figure 7). The system aims to provide additional information on disease incidence and contribute to WHO's global surveillance. A sentinel surveillance system can also be developed when high-quality data are needed about a particular disease that cannot be obtained through a passive system. For example, a network of clinics and hospitals are recruited by health departments in the United States to regularly report on the incidence of influenza.

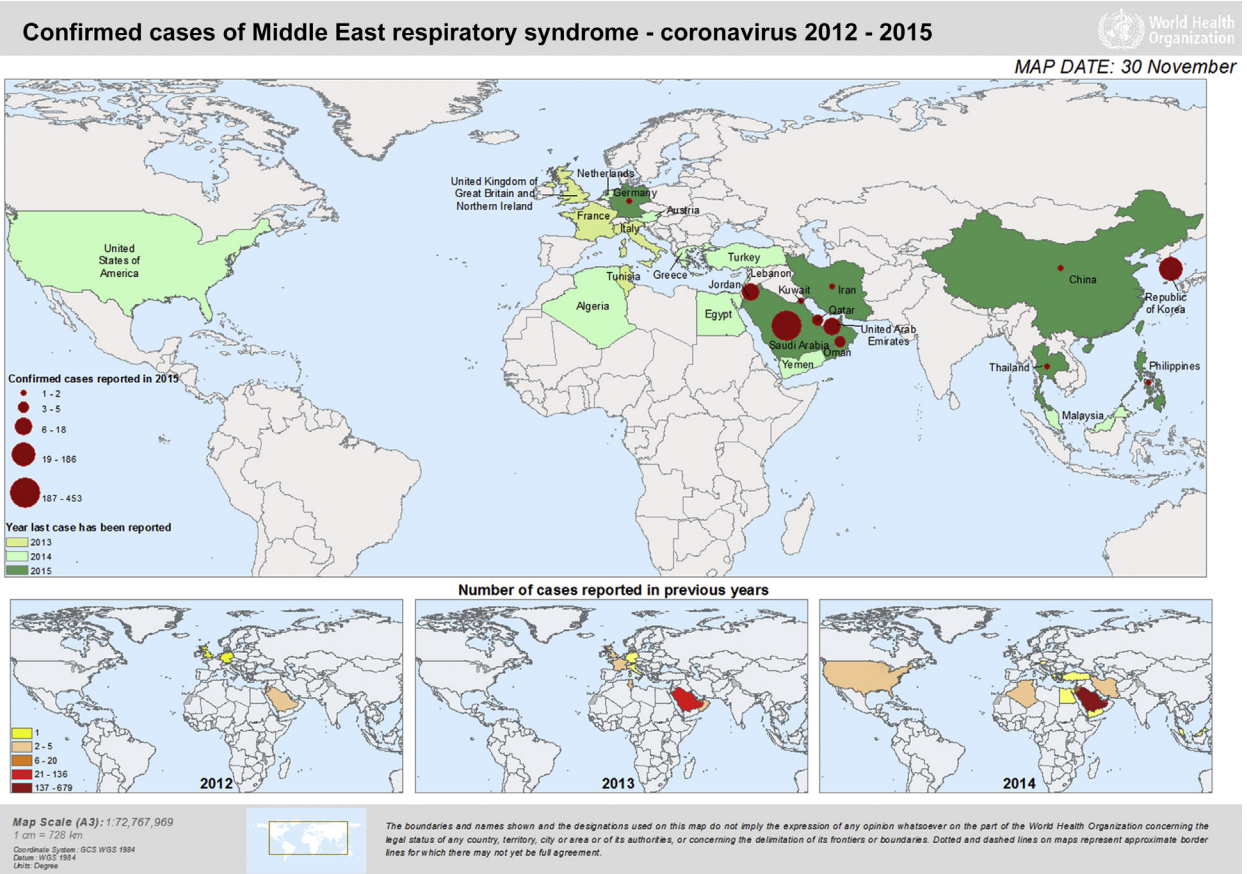


Figure 6 Global map of countries with confirmed cases of Middle East respiratory syndrome coronavirus (2012 through 30 Nov 2015). WHO. http://www.who.int/csr/disease/coronavirus_infections/maps-epicurves/en/ (accessed December 2015).

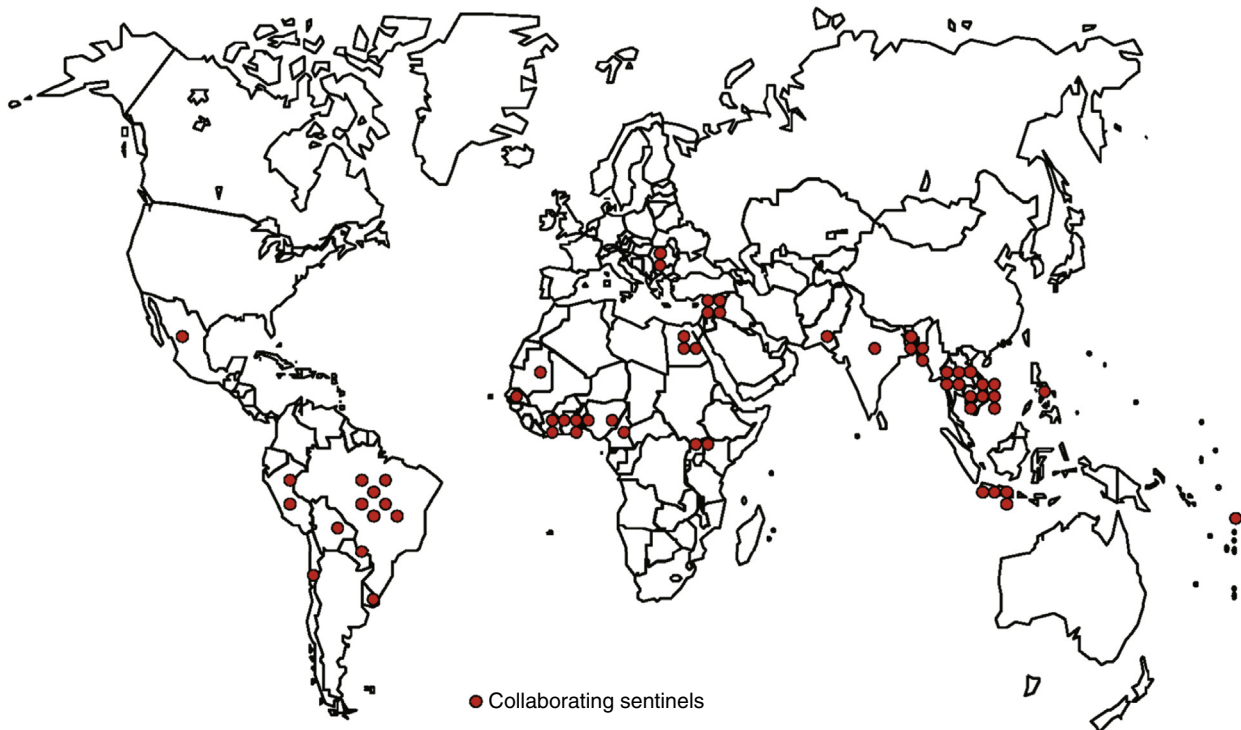


Figure 7 Distribution of collaborating sentinels in AGSnet surveillance network.

Smallpox Surveillance and Eradication

Smallpox was officially declared eradicated in 1980. Smallpox eradication was achieved as a result of an intensified WHO Smallpox Eradication Program launched in 1967 which combined focused surveillance with ring vaccination. The program effectively controlled smallpox and the last known natural case was in Somalia in 1977.

The first component of the program was to ensure reporting of cases from the village/town level to the district and national levels, and subsequently to the WHO regional offices and finally to WHO headquarters.

Surveillance activities were divided into two groups: smallpox-endemic countries (30 countries) and smallpox-free countries. Smallpox-endemic countries had a less effective surveillance system with significant number of unreported cases. In contrast, smallpox-free countries provided accurate reports. Under the International Health Regulations, reporting of smallpox is obligatory. The occurrence of smallpox in a smallpox-free country is regarded as a national emergency that requires immediate containment actions and reporting to the WHO. The WHO Smallpox Eradication Program requires weekly reporting of cases from both smallpox-endemic and smallpox-free countries, as well as zero reporting from endemic countries.

The working principles for the surveillance activities undertaken in smallpox-endemic countries include the following:

1. Smallpox has no subclinical infection, and its clinical manifestation is distinct. This increases the sensitivity of surveillance greatly. The picture cards invented by officials in the Indonesian surveillance program, termed 'smallpox recognition cards,' were effectively deployed in the entire global smallpox eradication program (Figure 8). Villagers could immediately recognize what an individual infected with smallpox looked like and understood the need to report such individuals to the surveillance officer.
2. The distinct clinical manifestation did not require laboratory confirmation, when the disease was known to be endemic (Figure 9). Only when the disease became rare was



Figure 8 Active search for smallpox case. Surveillance officer showing smallpox recognition card to villagers in South Asia. Smallpox was known to villagers because of its typical clinical picture. Hence, this method is effective as far as villagers want to collaborate.

laboratory confirmation required. This greatly simplified surveillance procedures.

3. In India, despite the implementation of an intensive national vaccination program targeting 100% vaccination coverage of the entire population for more than 5 years, the transmission of smallpox continued (Figure 10). The then-prime minister instructed all health center staff (more than 200 health centers were involved) to close the center for 1 week each month and go into the villages to actively search for smallpox cases. Whenever a case was found, immediate ring vaccination of the entire village was instituted. This special campaign, termed 'The Autumn Campaign,' started in September 1973, and the final smallpox case was detected in May 1975. This campaign showed the effectiveness of a focused surveillance and containment strategy. Since then, India and the world have remained smallpox-free.

During the 2-year certification period, extensive efforts were employed to search for any hidden focus of infection in previously smallpox-endemic countries and their adjacent countries, including house-to-house surveillance visits. It was determined that 2 years of effective surveillance must elapse before this last endemic area can be confirmed to be smallpox-free. Two years was twice the interval between the last and second last cases of naturally occurring smallpox.

Although the smallpox disease has been eradicated, the etiologic agent is not extinct. The virus continues to exist in freezers in secure facilities at the US Centers for Disease Control and Prevention in Atlanta, Georgia, and the Russian State Research Center of Virology and Biotechnology in Koltsovo. There is a continuing debate on whether to irreversibly destroy the two final samples of the smallpox virus and to assure the public that smallpox will never again be a threat to humankind. However, opponents of it maintain that the samples may be needed for further research as smallpox virus may still exist in the world outside of the two repositories, and may reemerge, particularly as a bioweapon.

Influenza Surveillance and Pandemics

In the twentieth century, the world experienced three major pandemics – 'Spanish flu' influenza A(H1N1) in 1918–19, 'Asian flu' influenza A(H2N2) in 1957–58, and 'Hong Kong flu' influenza A(H3N2) in 1968–69. The first influenza pandemic of the twenty-first century occurred in 2009–10. The new influenza A(H1N1)pdm09 virus was first isolated from humans in Mexico and the United States in April 2009. This influenza pandemic had two outstanding characteristics. First, it was able to cause major out-of-season epidemics in temperate countries, occurring in the spring and summer months. Second, it caused unusually severe disease and death among the young and in healthy people. It was the first influenza pandemic for which both antiviral drugs and vaccines were deployed and for which national pandemic preparedness plans were put in effect in developed countries and many lower-income countries. Arising from this pandemic, the WHO's pandemic preparedness guidance was revised to provide a risk-based approach to management of the pandemic

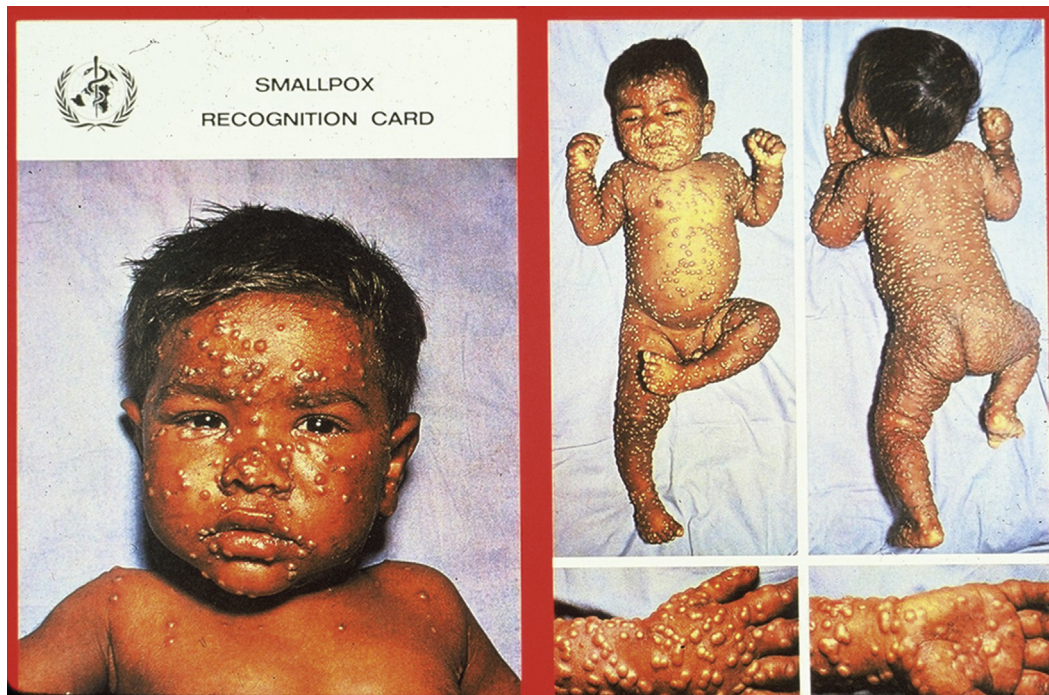


Figure 9 Clinical manifestation is typical for smallpox. Hence, routine report does not need laboratory confirmation.

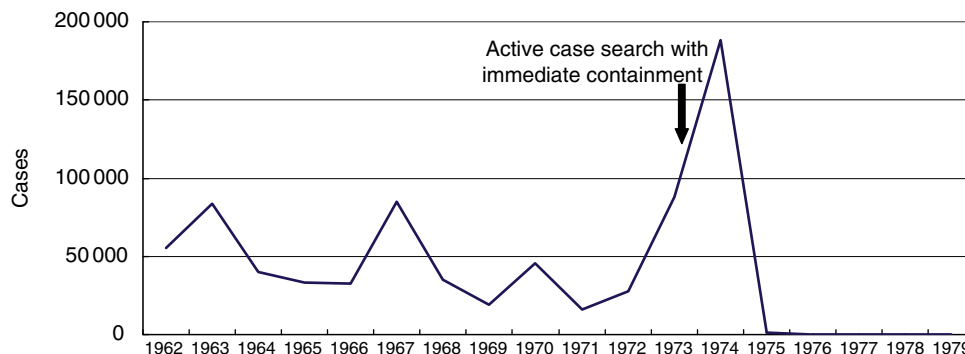


Figure 10 Number of smallpox cases reported by year in India. Active search discovered some 200 000 cases, which otherwise were not reported to the program. Thus, containment was more effective. The campaign resulted in a sharp incidence increase in 1973 and 1974. The transmission was interrupted in 1975.

based on the evolving virological, epidemiological, and clinical data (Table 1).

Recognizing the Event

Epidemiological signals, such as a sudden increase in the number of individuals with unexplained respiratory illness (with or without accompanying high mortality) in a geographical area over a short period of time, are likely to be the most sensitive indicator of a suspected pandemic event. Active surveillance of respiratory infections and pneumonia in hospitals would be necessary to determine the illness severity. The event could be related to epidemics in animal populations, for which surveillance of animal influenza is important. This will be discussed in the next section. Following the detection

of a cluster of suspected cases, investigations should be initiated as soon as possible to characterize the outbreak by time, place, and person and to identify the potential sources or reservoirs. Laboratory testing of respiratory samples to identify the causative agent should ideally be completed within 48 h of the cluster detection.

Surveillance of Animal Influenza

Influenza A viruses originating from animals can adapt to infect humans following a genetic mutation or exchange. Identification and characterization of circulating animal influenza viruses are therefore crucial for human influenza pandemic preparedness. The primary risk factor for human infection appears to be the direct or indirect exposure to infected live

Table 1 WHO global influenza pandemic phases (as of December 2015)

Interpandemic phase	This is the period between influenza pandemics.
Alert phase	This is the phase when influenza caused by a new subtype has been identified in humans. Increased vigilance and careful risk assessment, at local, national and global levels, are characteristic of this phase. If the risk assessments indicate that the new virus is not developing into a pandemic strain, a deescalation of activities toward those in the interpandemic phase may occur characteristic of this phase.
Pandemic phase	This is the period of global spread of human influenza caused by a new subtype. Movement between the interpandemic, alert, and pandemic phases may occur quickly or gradually as indicated by the global risk assessment, principally based on virological, epidemiological, and clinical data.
Transition phase	As the assessed global risk reduces, deescalation of global actions may occur, and reduction in response activities or movement toward recovery actions by countries may be appropriate, according to their own risk assessments.

Source: Pandemic Influenza Risk Management WHO Interim Guidance. http://www.who.int/influenza/preparedness/pandemic/GIP_PandemicInfluenzaRiskManagementInterimGuidance_Jun2013.pdf?ua=1 (accessed December 2015).

or dead animals or contaminated environments. As described in the WHO Manual on Animal Influenza Diagnosis and Surveillance, the objective of surveillance in lower animals (such as pigs) and birds is to complement the human influenza surveillance network, to understand the ecology of influenza viruses that are relevant to human and animal health, to determine the molecular basis of host range transmission and the spread in new hosts, and to identify molecular markers of influenza viruses that can transmit between species especially to humans.

Notification to National Health Authorities

Local health authorities should be alert and respond with a high level of suspicion and notify national health authorities as soon as there is suggestion that a respiratory cluster is unusual or unexpected.

Notification to the WHO

Under the International Health Regulations 2005, human influenza caused by a new subtype is deemed always to be unusual or unexpected and may have serious public health impact, and hence must be notified to the WHO at all circumstances.

Avian influenza A(H7N9) is a subtype of influenza viruses that have been detected in birds in the past. Human infections with a new avian influenza A(H7N9) virus were first reported in China in March 2013. The infection has the propensity to cause severe illness. Most individuals infected with the avian influenza A(H7N9) virus have reported exposure to live poultry or potentially contaminated environments, especially markets

where live birds or poultry have been sold. Although a few family clusters have been reported, there is no evidence to support sustained human-to-human transmission. Since the first human infection in March 2013 to 15 October 2015, a total of 679 laboratory confirmed human infections with avian influenza A(H7N9), including 275 (40%) deaths, have been reported to the WHO.

Polio Surveillance and Eradication

Polio vaccination has successfully eradicated polio in many regions in the world. However, failure to eradicate polio in the remaining countries continues to pose international risks. The WHO's Polio Eradication and Endgame Strategic Plan 2013–2018 was launched to eradicate all types of polio disease simultaneously – both due to wild poliovirus and due to vaccine-derived polioviruses. On 5 May 2014, the WHO declared the international spread of wild poliovirus in 2014 a Public Health Emergency of International Concern (PHEIC). Afghanistan and Pakistan had exported wild poliovirus to vulnerable countries. With the declaration of PHEIC and the implementation of Temporary Recommendations issued by the Director-General of the WHO, as of 10 November 2015, there has been an overall decline in the occurrence of international spread of wild poliovirus, with no cases reported in Africa for more than 12 months, and Nigeria interrupting endemic transmission of wild poliovirus. From 1 January to 25 November 2015, 57 cases of wild poliovirus have been reported in two countries, Afghanistan and Pakistan, compared to 305 cases from nine countries over the same period in 2014. Pakistan reported the largest number of polio cases.

AFP Surveillance

Nationwide AFP surveillance is the gold standard for the detection of poliomyelitis. AFP surveillance includes the following four steps:

1. finding and reporting children with AFP;
2. collecting stool samples for analysis;
3. isolating and identifying poliovirus in the laboratory;
4. mapping the poliovirus (if identified) to determine the origin of the virus strain.

Nationwide active case finding would require the assistance and support of all health-care facilities including large hospitals in urban areas down to the dispensaries and health centers in rural areas. In the rural areas in Africa, where health-care facilities are sparse, community-based AFP surveillance is necessary for identification of polio cases. The support of community leaders, including senior members of the community and faith leaders, is crucial for the work.

Laboratory Surveillance

For confirmation of poliomyelitis, virus isolation should be performed on two stool specimens collected at least 24 h apart within 14 days of the onset of paralysis. As poliovirus is excreted in the feces during the acute phase of the illness, specimens taken early in the course of the illness would give the best yield. To ensure the viability of the virus, the temperature during the transport of the samples should be kept at 2–10 °C. Laboratory results (especially

so if poliovirus was detected) should be rapidly communicated to the relevant public health authorities for timely action.

Surveillance Indicators

To meet WHO's minimum standards level of performance for AFP surveillance, at least 80% of expected routine (weekly or monthly) AFP surveillance reports should be received on time, at least one case of nonpolio AFP should be detected annually per 100 000 population aged less than 15 years (2 per 100 000 for endemic regions), all AFP cases should have a full clinical and virological investigation with at least 80% of AFP cases having adequate stool specimens collected, at least 80% of AFP cases should have a follow-up examination for residual paralysis at 60 days after the onset of paralysis, all AFP case specimens must be processed in a WHO-accredited laboratory within the Global Polio Laboratory Network (GPLN). AFP surveillance can be expected to continue until the polio eradication is achieved.

Measles Surveillance

Measles is the most contagious viral disease, with a basic reproduction number (R_0) of 12–18. This means that one measles case can infect 12–18 cases over the course of its infectious period, in a previously uninfected and susceptible population. Until the measles vaccine was introduced in 1963, practically every child got measles. While there is an effective vaccine, measles vaccination coverage has declined over the years resulting in measles outbreaks in unvaccinated populations. A vaccination coverage rate of 95% in a population is required in order to achieve herd immunity.

The 2012–2020 Global Measles and Rubella Strategic Plan focuses on the implementation of five core components for measles and rubella elimination, which include the attainment of high vaccination coverage with two doses of measles- and rubella-containing vaccines and the close monitoring of disease using effective surveillance. The primary objective of measles surveillance is for timely detection of all areas in which the measles virus is circulating, but not necessarily to detect every measles case. This requires the timely notification and investigation of suspected measles cases. Detection of measles-specific IgM antibodies is important for the confirmation of measles infection in suspected cases. A single serum sample collected within 28 days of rash onset of rash can provide presumptive evidence of a current or recent measles virus infection. In previously vaccinated persons, often there is a blunted and/or transient production of IgM and therefore a negative IgM test in vaccinated persons suspected of having measles should not be used to rule out the case. A PCR test may be the best method to confirm such cases.

Community-based measles surveillance may be required in areas where health-care facilities are nonexistent. The establishment of a system for the syndromic reporting of acute febrile rash illness followed by procedures for the collection and testing of blood samples for laboratory diagnosis would be necessary.

Ebola Virus Disease Surveillance

Since the discovery of the EVD in Central Africa in 1976, the disease has been the focus of national and international surveillance with the increasing transmission risks as a result of higher travel volume and frequency in Africa. In 2013–15, the world experienced the most widespread EVD epidemic to date. An outbreak of EVD that started in Guinea in December 2013 spread extensively to Liberia and Sierra Leone and caused a small outbreak in Nigeria and several cases in Mali. Isolated cases occurred in Senegal, Sardinia, and the United Kingdom, subsequently. On 8 August 2014, WHO declared the EVD epidemic in West Africa a PHEIC. Imported cases in the United States and Spain led to secondary infections of medical workers but did not spread further. As of 2 December 2015, a total of 28 638 suspected cases and 11 315 deaths were reported. On 7 October 2015, all three of the most seriously affected countries (Guinea, Liberia, and Sierra Leone) recorded the first joint week without any new cases, raising hopes that the epidemic might finally be coming to an end. However, sporadic new cases continue to emerge, and a family cluster of three confirmed EVD cases were reported in Liberia on 20 November 2015. The recurrence of EVD in Liberia, after twice previously declared EVD-free only to have new EVD cases appear, is a reminder for the EVD-affected countries to remain vigilant for recurrence and highlights the importance of continued surveillance.

Surveillance is aimed at the early detection of cases for isolation and strict barrier nursing to prevent transmission. Contact tracing and close follow-up of exposed individuals is crucial. All health-care staff should be educated on the nature of the disease and the routes of transmission. They should be trained in the proper donning and doffing of personal protective equipment and in infection prevention practices including good hand hygiene and the necessary contact precautions when handling the blood and body fluids of the infected person. Efforts should be made to ensure that communities affected by EVD are well informed, about the disease itself and the symptoms to look out for and the need to seek immediate medical attention when they arise. The community should also be informed about the crucial infection prevention measures, including good personal hygiene and the proper handling of the dead and safe burial procedures. As the primary mode of transmission is person-to-person transmission via contact with infected blood and/or body fluids, any individual who had had close physical contact with EVD patients should be kept under close surveillance. EVD surveillance is a typical surveillance model whereby surveillance and disease control are highly interrelated.

EVD is characterized by the sudden onset of fever, intense weakness, muscle pain, headache, and sore throat. This is often followed by vomiting, diarrhea, rash, impaired kidney and liver functions, and in some cases, internal and external bleeding. Specialized laboratory tests on blood specimens can detect the specific antigens or genes of the Ebola virus. Antibodies to the virus can also be detected and the virus isolated in cell culture. For patient management, supportive care is the main stay of treatment. At this time, there is no specific drug or vaccine for EVD. Clinical trials on convalescent plasma and

vaccines are ongoing. A safe and effective EVD vaccine is hoped for by the end of 2015.

Surveillance of Noncommunicable Diseases

In addition to the surveillance of communicable diseases as described in the preceding sections, public health surveillance includes surveillance of noncommunicable diseases (NCDs). Although communicable diseases are the leading causes of death in low-income countries, NCDs are the leading

causes of death in lower-middle to high-income countries (Figure 11(a–d)). Globally, NCDs, such as heart disease, stroke, cancer, chronic respiratory diseases, and diabetes, represent 60% of all deaths. In the following sections, surveillance of the risk factors for NCDs and selected NCDs will be discussed.

Surveillance on Risk Factors for NCDs

As part of a global strategy for preventing and controlling NCDs, the WHO developed a STEPwise approach to surveillance of risk factors for NCD (STEPS) using a standard survey

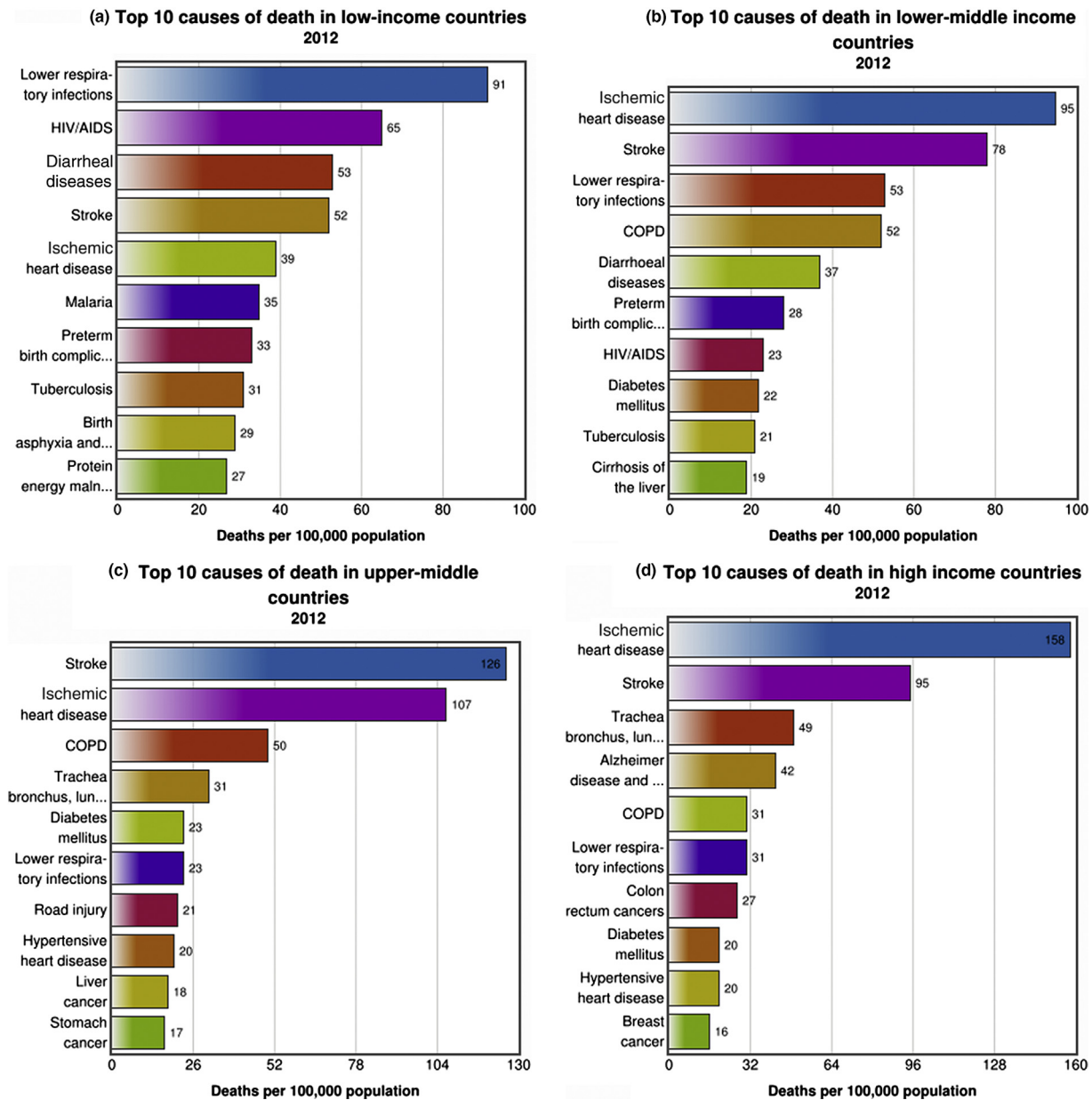


Figure 11 (a) Top 10 causes of death in low-income countries. (WHO Fact Sheet. <http://www.who.int/mediacentre/factsheets/fs310/en/index1.html> (accessed December 2015).) (b) Top 10 causes of death in lower-middle income countries. (WHO Fact Sheet. <http://www.who.int/mediacentre/factsheets/fs310/en/index1.html> (accessed December 2015).) (c) Top 10 causes of death in upper-middle income countries. (WHO Fact Sheet. <http://www.who.int/mediacentre/factsheets/fs310/en/index1.html> (accessed December 2015).) (d) Top 10 causes of death in high-income countries. (WHO Fact Sheet. <http://www.who.int/mediacentre/factsheets/fs310/en/index1.html> (accessed December 2015).)

instrument and methodology that can be adapted to different countries and resource settings. STEPS encourages the collection of small amounts of useful data on a regular and continuing basis and focuses on a minimum number of risk factors that predict the major NCDs. This minimizes the need for costly disease registries that may be unsustainable in low- and lower-middle income countries. The STEPS approach has three steps and gathers core and expanded information on risk factors through: step 1 – use of questionnaires (sociodemographic factors, tobacco use, alcohol consumption, physical activity, and fruit and vegetable intake); step 2 – physical measurements (height, weight, waist circumference, and blood pressure); and step 3 – biochemical measurements (lipid profile and glucose level). Step 1 and step 2 are desirable and appropriate for most developing countries. The information would be useful for the planning of NCD prevention strategies through population-level risk factor reduction.

Epidemiological Surveillance Research on Stroke and Cardiovascular Diseases

In Hisayama Town (population of 7000) in Japan, three cohort studies were conducted on residents aged 40 and above who had health screening examinations in 1961, 1974, and 1988. The cohorts were followed up longitudinally with repeated health examinations (follow-up rate, 99%). When the study participants died, autopsy examinations were performed (autopsy rate, >80%). The initial objective of the study was to assess for the prevalence and risk factors of stroke, but was expanded to include cardiovascular diseases, cancer, senile dementia, diabetes, and other lifestyle-related diseases. Subsequently, a molecular epidemiological study was added to assess for genomic risk factors. The findings from the study have contributed significantly to the development of national policies on NCD prevention.

In the United States, the National Health and Nutrition Examination Survey (NHANES) program assesses the prevalence of major NCDs and risk factors. The NHANES program which began in the early 1960s is conducted annually and examines a nationally representative sample of about 5000 individuals each year from counties across the country. Information from the program is used to assess nutritional status and its association with health promotion and disease prevention. Data from the program are also used in epidemiological studies and health services research to help develop sound public health policies, direct and design health programs and services, and expand the health knowledge of the country.

The Singapore Chinese Health Study followed up a cohort of 63 257 ethnic Chinese men and women aged 45–74 years who were permanent residents or citizens of Singapore, recruited between 1993 and 1998. At recruitment, each study participant completed a validated, 165-item food frequency questionnaire. By April 2005, all surviving cohort participants had been recontacted for biospecimen donation. Samples were obtained from 32 543 subjects (28 330 blood, 4400 buccal cell, and 31 895 urine samples). The cohort has been followed for death, cancer incidence, and other major health outcomes through regular record linkages with the population-based Singapore Cancer Registry and the Singapore

Registry of Births and Deaths, and through telephone follow-up interviews. This prospective cohort study has contributed a wealth of knowledge on the role of dietary and other environmental factors in the etiology of cancer. Findings from this study indicated a protective effect of dietary isothiocyanates on colon cancer risk and an inverse association between soy intake and markers of breast cancer risk. These results have helped shape national health promotion and cancer prevention strategies.

Cancer Registries

Cancer registries are part of the national NCD surveillance system. Population-based registries provide invaluable information on the trends in cancer incidence, while hospital-based registries provide information on the clinical diagnosis, cancer staging, treatment modalities, and survival outcomes. In Japan, cancer incidence is monitored through population-based and hospital-based cancer registries by the Japanese Association of Cancer Registries, in collaboration with 34 prefectural governments. The registries are supported and maintained by the Research Center for Cancer Prevention and Screening at the National Cancer Center. In Singapore, a comprehensive population-, clinic-, hospital-, and laboratory-based cancer registration has been performed by the Singapore Cancer Registry since 1968. Comprehensive cancer registration has been achieved through collation of data obtained from a combination of sources: (1) physician notifications, (2) pathology records, (3) hospital records, and (4) mortality data from the national Registry of Births and Deaths. Since 2009, cancer notification has been made mandatory to ensure completeness of surveillance.

Surveillance of Injuries and Violence

Injuries and violence are major public health problems but have been neglected for many years, despite being predictable and largely preventable. In 2012, the WHO estimates that more than 5 million people die each year as a result of injuries, accounting for 9% of the world's deaths and being nearly 1.7 times the number of fatalities from HIV/AIDS, tuberculosis, and malaria combined. One-quarter of the deaths from injuries are the result of self-inflicted injuries (suicide and homicide), while road traffic injuries account for another quarter. The other leading causes of death from injuries were falls, drowning, burns, poisoning, and war. The cost of injury-related morbidity and mortality is immense in terms of missed economic opportunity, increased health-care expenditure, loss of productivity, and personal suffering. The highest rates of death and permanent disability due to injury are, however, currently found in poorer countries (Figure 12). To develop effective injury prevention strategies, these countries would need better information. However, few of them have surveillance systems that generate reliable information on the nature and frequency of injuries. Aiming to collect better information to develop effective preventive strategies, the WHO, in collaboration with the US CDC, has produced manuals on how to set up surveillance systems for collecting, coding, and processing relevant data. In active surveillance, injury cases are actively sought out and investigated. Injured

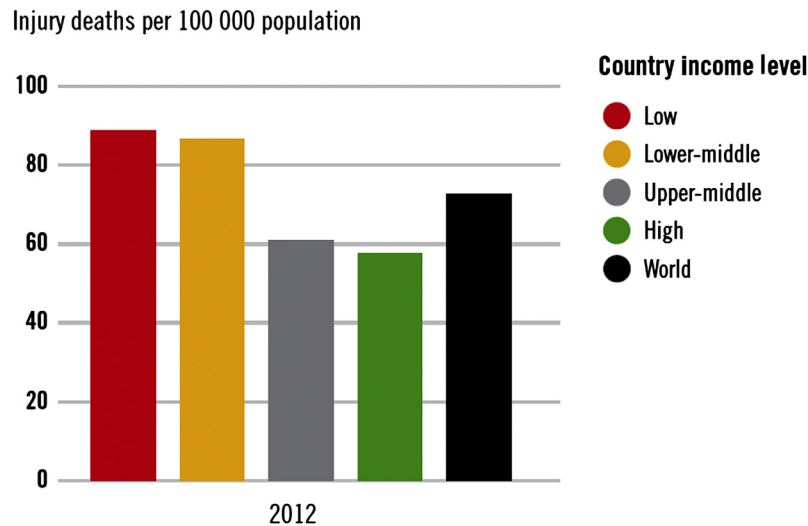


Figure 12 Injury death rates by country income level in 2012. WHO. Injuries and violence: the facts 2014.

individuals are interviewed and followed up. For example, the active surveillance of child abuse would involve identifying and locating cases through a variety of sources such as police reports, social agencies, and educational authorities. It might also include seeking out the abused children, their parents, and/or the appropriate authorities. Relevant data are collected in the course of routine tasks. For example, doctors are routinely required to fill out death certificates as required by the law, but it is possible to extract data provided in the death certificates to obtain information on deaths from injuries. Forms filled out by doctors and nurses for the purposes of medical insurance claims can also be used for surveillance. Other potential data sources for fatal injuries include autopsy/pathology reports and police reports, and surveillance sources for nonfatal severe injuries include trauma registries and ambulance or emergency medical technician records. In Japan, the statistics on fatal and nonfatal injuries, including accidents and suicides, are available from police reports, the Population Survey Report, and death certificates. Community-based surveys can complement injury and violence surveillance by capturing injury events in the community that did not present to formal health-care facilities or were so minor that did not require medical attention.

Global Surveillance Network

The WHO closely monitors and tracks the evolving infectious disease situation and sounds the alert when needed. The WHO global alert and response systematically gathers official reports and rumors of suspected outbreaks from a wide range of formal and informal sources. Formal reports of suspected clusters or outbreaks are received from ministries/departments of health, national institutes of public health, WHO Regional and Country offices, WHO collaborating centers, civilian and military laboratories, academic institutes, and nongovernmental organizations. The WHO has also developed a comprehensive 'event management system' to

manage critical information about outbreaks and ensure accurate and timely communications between key international public health professionals, including WHO Regional Offices, Country Offices, collaborating centers, and partners in the Global Outbreak Alert and Response Network (GOARN) (Figure 13).

In 2005, the WHO and member states renewed the International Health Regulations (IHR) whose purpose was to "ensure the maximum protection of people against the international spread, while minimizing interference with world travel and trade." Figure 14 summarizes the information flow of events of public health emergency of international concern from the national surveillance office to the WHO, under the IHR 2005. Through the IHR, the WHO also keeps countries informed about public health risks (Figure 15) and works with partners to help countries build capacity to detect, report, and respond to public health events.

The unprecedented development of technologies has greatly enhanced global surveillance. Novel pathogens such as the MERS-CoV virus can be quickly identified using advanced molecular techniques and real-time reporting and sharing of information made possible via the internet. On the other hand, the rapid expansion in the world population (estimated at 7.3 billion in July 2015) and the increased frequency of travel by air, sea, and land have accelerated the speed of disease transmission. The situation is worsened by income inequality. According to the World Bank's most recent estimates, in 2012, 12.8% of the world's population lived at or below \$1.90 a day (Table 2). This meant that, in 2012, 902 million people lived on less than \$1.90 a day. In sub-Saharan Africa, extreme poverty and the incidence of severe diseases form a vicious cycle and may pose a threat to neighboring geographical regions. The limited resources and inadequate health-care facilities, coupled with political unrest in some regions, render surveillance in sub-Saharan Africa ineffective. The importance of global collaboration to strengthen surveillance in these areas cannot be overemphasized.

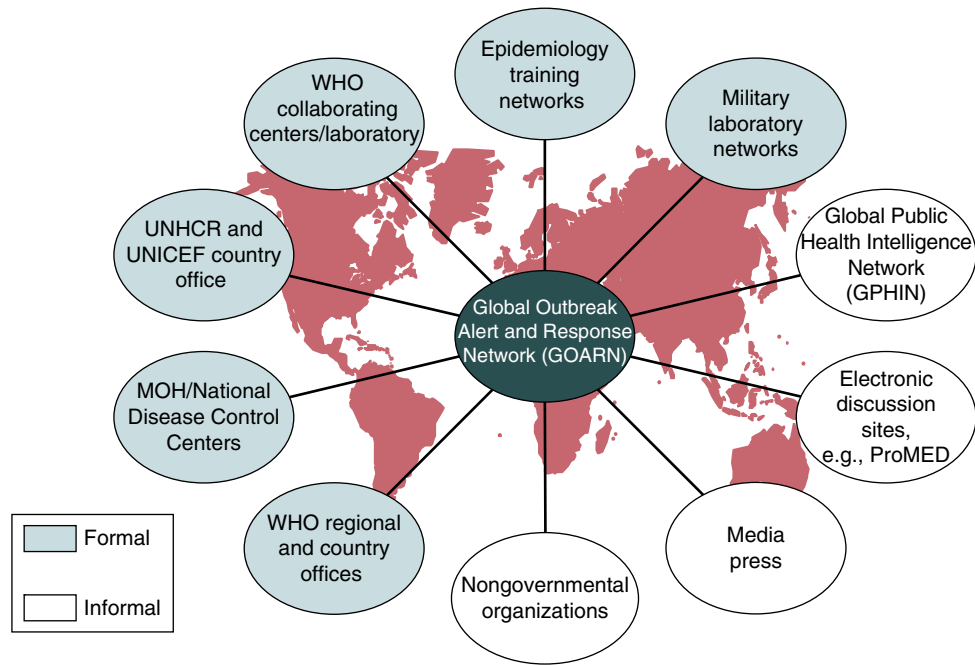


Figure 13 Global surveillance of communicable diseases: network of networks. With the growing importance of worldwide surveillance on emerging and reemerging diseases, surveillance networks have been developed by WHO and various organizations, research centers, and nongovernmental organizations.

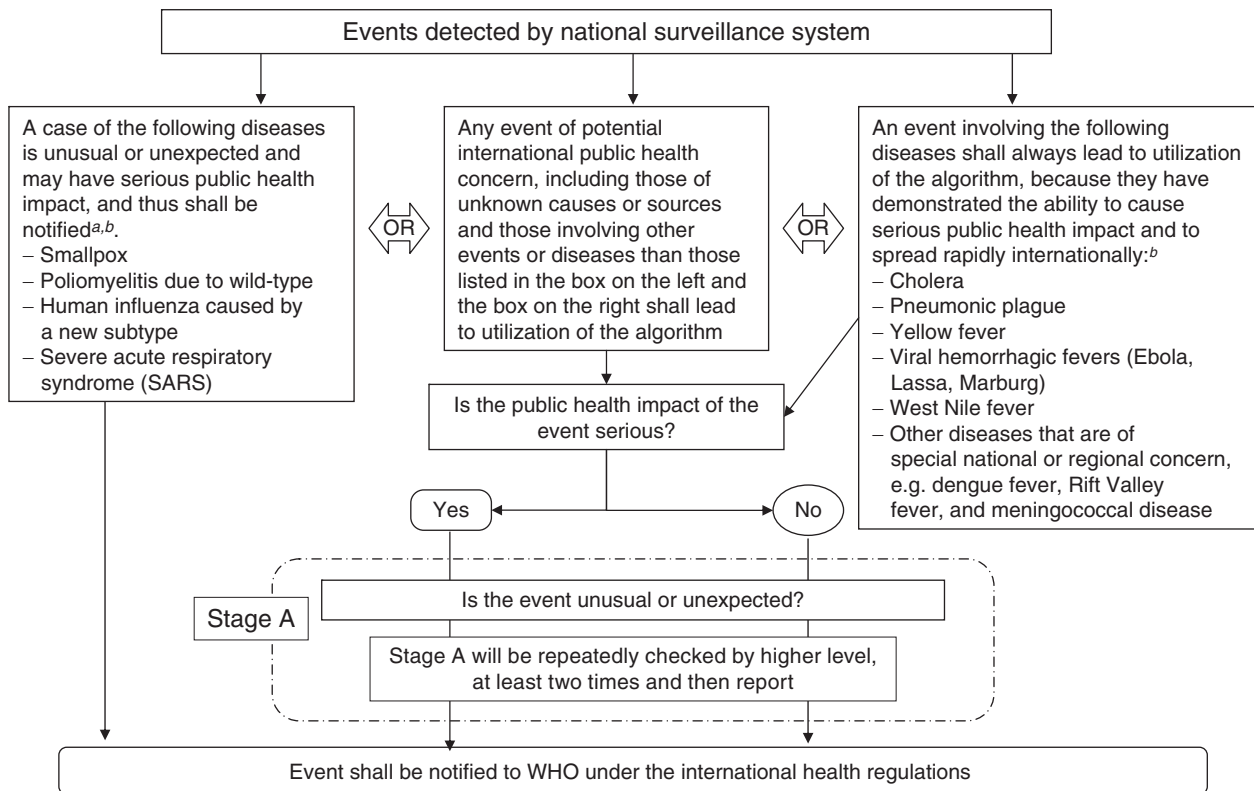


Figure 14 Notification system of events that may constitute a public health emergency of international concern, as required under the International Health Regulations (2005). (a) As per WHO case definitions. (b) The disease list shall be used only for the purposes of the Regulations. Source: WHO. http://www.apps.who.int/iris/bitstream/10665/43883/1/9789241580410_eng.pdf.

The screenshot shows the WHO Disease Outbreak News (DONs) website. The header includes the WHO logo and navigation links in multiple languages. The main navigation bar has 'Programmes' highlighted. Below this, the page title is 'Emergencies preparedness, response'. The 'Disease Outbreak News (DONs)' section is the primary focus, containing a 'New information' box with a 'Latest DON' link, a 'Recent DONs' list with three entries from December 2015, and sections for 'Related links' and 'Related documents'.

Figure 15 WHO epidemic and pandemic alert and response. From WHO Disease Outbreak News. <http://www.who.int/csr/don/en> (accessed December 2015).

Table 2 World Bank estimates of extreme poverty (living on less than \$1.90 a day), 1990–2015

Region	Historical			Headline	Projection
	1990	1999	2011	2012	2015 ^a
Share of population below \$1.90 a day (2011 PPP)					
East Asia and Pacific	60.8	37.5	8.5	7.2	4.1
Europe and Central Asia	1.9	7.8	2.7	2.5	1.7
Latin America and the Caribbean	17.7	14.1	6.5	6.2	5.6
Middle East and North Africa ^b	–	–	–	–	–
South Asia	50.6	41.2	22.2	18.8	13.5
Sub-Saharan Africa	56	58.1	44.3	42.6	35.2
<i>Developing world</i>	44.3	34.2	16.6	15.0	11.9
<i>World</i>	37.1	29.0	14.2	12.8	9.6
Millions of people below \$1.90 a day (2011 PPP)					
East Asia and Pacific	999.3	689.7	173.1	147.2	82.6
Europe and Central Asia	9.0	36.6	12.7	12.0	4.4
Latin America and the Caribbean	78.0	72.2	37.7	37.1	29.7
Middle East and North Africa ^b	–	–	–	–	–
South Asia	574.5	560.1	362.3	309.2	231.3
Sub-Saharan Africa	284.0	375.4	393.5	388.5	347.1
<i>World</i>	1958.5	1746.6	987.4	902.0	702.1

^aDue to the production lags for household surveys, 2012 is the latest year for which the World Bank is able to produce regional and global poverty estimates. Numbers for 2015 are statistical projections based on growth scenarios and distributional assumptions.

^bAlthough five countries in the Middle East and North Africa (MNA) region are omitted from the database of country level poverty estimates, poverty estimates for these countries are calculated for the purposes of global poverty estimation. The 2011 and 2012 MNA regional poverty estimates implied by these global estimates are 2.4 and 2.3 percent, respectively.

Source: World Bank Group. Ending Extreme Poverty and Sharing Prosperity: Progress and Policies. <http://www.pubdocs.worldbank.org/pubdocs/publicdoc/2015/10/109701443800596288/PRN03-Oct2015-TwinGoals.pdf> (accessed December 2015).

Global surveillance requires the cooperation of all WHO member states. The WHO Assembly, as and when necessary, reviews and makes recommendations on how member states and relevant experts can contribute to the effective performance of international surveillance in different geographical

locations. It is important to note that the surveillance activities in areas of extreme poverty would require substantial support from richer nations. Such international cooperation would be necessary for the collective development of an effective global surveillance system.

Ethical and Legal Aspects of Surveillance

Surveillance activities often involve surveillance workers handling communities, people, and institutions in health hazard investigation, collection of technical and private information, and publication of collated information. It is important that the purposes of surveillance be made known and explained fully to individuals and the community so that surveillance teams can obtain the required information with the cooperation of the involved individuals and community. When planned, surveillance activities should be carried out with the protection of the respective individual's or organization's privacy. In some cases, there may be a tension between the individual's right to privacy and the surveillance team's right to information. Statutory laws may be necessary to balance individual rights against public health necessities.

Further Reading

- Arita, I., Na kane, M., Kojima, K., Yoshihara, N., Nakan, O.T., El-Gohary, A., 2004. Role of a sentinel surveillance system in the context of global surveillance of infectious diseases. *Lancet Infect. Dis.* 4 (3), 171–177.
- Centers for Disease Control and Prevention, 2012. CDC's vision for public health surveillance in the 21st century. *MMWR* 61 (Suppl.), 1–40.
- Fenner, F., Henderson, D.A., Arita, I., et al., 1988. *Smallpox and Its Eradication*. World Health Organization, Geneva, Switzerland.
- Heymann, D.L., Rodier, G.R., 1998. Global surveillance of communicable diseases. *Emerg. Infect. Dis.* 4 (3), 362–365.
- Lee, L.M., Teutsch, S.M., Thacker, S.B., St Louis, M.E., 2010. *Principles and Practice of Public Health Surveillance*, third ed. Oxford University Press, New York.
- World Health Organization, 1999. WHO Recommended Surveillance Standards. WHO/CDS/CSR/ISR/99/2/EN, second ed. World Health Organization, Geneva, Switzerland.
- World Health Organization, 2005. Preventing Chronic Diseases: A Vital Investment. WHO Global Report. http://www.who.int/chp/chronic_disease_report/full_report.pdf?ua=1 (accessed December 2015).
- World Health Organization, 2007. Injury Surveillance Guidelines. http://www.who.int/violence_injury_prevention/publications/surveillance/surveillance_guidelines/en/ (accessed December 2015).

Relevant Websites

- <http://www.polioeradication.org/> – Global Polio Eradication Initiative (last accessed 16.06.16.).
- <http://www.measlesrubellainitiative.org/> – Measles and Rubella Initiative (last accessed 16.06.16.).
- <http://www.who.int/csr/en/> – World Health Organization, Epidemic and Pandemic Alert and Response (last accessed 16.06.16.).
- <http://www.who.int/flu/en/> – World Health Organization, Global Influenza Programme (last accessed 16.06.16.).
- <http://www.who.int/csr/ihr/en/> – World Health Organization, International Health Regulation, 2005 (last accessed 16.06.16.).
- http://www.who.int/ncd_surveillance/en/ – World Health Organization, Non-communicable Disease Surveillance (last accessed 16.06.16.).
- http://www.who.int/violence_injury_prevention/ – World Health Organization, Violence and Injury Prevention (last accessed 16.06.16.).
- <http://www.who.int/wer/en/> – World Health Organization, Weekly Epidemiological Record (last accessed 16.06.16.).