Infectious Disease Surveillance

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Goals of Infectious Disease Surveillance

Infectious disease surveillance is an important epidemiological tool to monitor the health of a population. The goals of infectious disease surveillance are threefold: (1) to describe the current burden and epidemiology of disease, (2) to monitor trends, and (3) to identify outbreaks and new pathogens. First, describing the burden and epidemiology (including seasonality, age distribution, age groups, etc.) of disease is critical for demonstrating the need and advocating for interventions, such as vaccination and mass drug administration. Surveillance is also used to detect antimicrobial resistance in certain pathogens (for example, fluoroquinolone resistance in gonorrhea) and the circulating strains of disease, which helps target vaccine interventions (for example, annual influenza vaccine composition).

Second, infectious disease surveillance is used to monitor disease trends, such as the impact of interventions like vaccination. Disease trends do not only mean the number of cases, but also the etiology of cases. For example, after pneumococcal conjugate vaccine introduction, the distribution of serotypes causing disease should be surveyed for serotype replacement, when the incidence of disease caused by serotypes not covered in the vaccine may increase following the decline in disease due to vaccine serotypes from vaccination. Information garnered from vaccine effectiveness studies can be coupled with burden and cost information to describe the cost-effectiveness of interventions.

Surveillance also monitors the control, elimination, and eradication of diseases. Disease control refers to reducing the incidence of disease to a desired level (which will vary depending on the disease) and includes diseases such as malaria (Dowdle, 1999). Disease elimination is defined as zero disease in a defined geographic area as a result of control measures. Progress toward disease elimination requires control measures to stay in effect. Disease eradication is defined as zero disease globally as a result of control measures, which are no longer required. Smallpox is the only human disease and rinderpest is the only animal disease that have been eradicated from the world, but efforts are underway to eradicate polio and dracunculiasis.

Finally, a key aspect of infectious disease surveillance is the cycle of detecting, responding to, and preventing outbreaks. Ongoing surveillance for an outbreak- and epidemic-prone disease can facilitate early detection of an outbreak, allowing a more rapid response and therefore mitigation of the outbreak. Epidemic meningococcal disease in the meningitis belt in Africa requires ongoing surveillance to identify outbreaks in the region. Cholera surveillance is maintained globally to detect outbreaks and requires mandatory reporting to the World Health Organization (WHO). Emerging and reemerging diseases also pose a big risk to public health. These diseases include both unknown pathogens that appear for the first time in a population as well as known pathogens that increase in geographic spread or severity or are reintroduced

into the population. The Zika outbreak in South America in 2015–16 demonstrates how rapidly a known pathogen in a naïve population can spread.

Infectious Disease Surveillance Methods

Infectious disease surveillance can have different approaches based on the epidemiology and clinical presentation of the disease and the goals of surveillance. We will discuss some distinctions between infectious disease surveillance methods and give examples below.

Active versus Passive Surveillance

In passive surveillance systems, medical professionals in the community and at health facilities report cases to the public health agency, which conducts data management and analysis once the data are received. Public health staff do not engage in identifying cases but rather assess data completeness and reliability of the reported cases. In contrast, active surveillance requires public health staff to engage actively in the system and take action in order to receive reports of disease cases. This may involve calling or visiting health facilities to encourage follow-up or having staff review medical records to identify cases meeting prescribed case definitions. Active surveillance aims to detect every case, and passive surveillance likely misses cases due to the reporting structure. Although active surveillance is more comprehensive, it requires significant human and financial resources, so passive surveillance is often implemented.

Notifiable disease surveillance is an example of passive surveillance. Notifiable diseases are classified as such because they are of public health importance: they can be a severe risk to human health, outbreak prone, considered to be an emerging or reemerging disease, or have a timely intervention available for control of the disease. Countries mandate which diseases are notifiable, many of which are infectious diseases. Globally, the WHO, as described in the International Health Regulations, defines what is notifiable by every country to WHO, such as MERS-CoV (Middle East respiratory syndrome coronavirus) and Ebola. Nationally notifiable diseases depend on the country. In the United States, the Centers for Disease Control and Prevention (CDC) and the Council of State and Territorial Epidemiologists compile a list of diseases that have mandated reporting to the CDC. These include foodborne and sexually transmitted infections, other infectious diseases such as dengue, malaria, and HIV, and noncommunicable diseases such as cancer. The list is updated every year. On 21 January 2016, the list was amended to include Zika virus disease after an outbreak in South America resulted in cases being imported into the United States.

Although not commonly used for surveillance purposes, administrative data or vital statistics are another example of routinely gathered data that can be used as passive surveillance. The International Classification of Diseases (ICD-10)

is used globally for the standard naming of diseases in hospitalized patients. Administrative data such as hospital billing data using ICD codes can be used for syndromic surveillance, such as for pneumonia, if it is available for ongoing monitoring of disease. These data may provide information on the clinical characteristics of patients across different regions and hospitals.
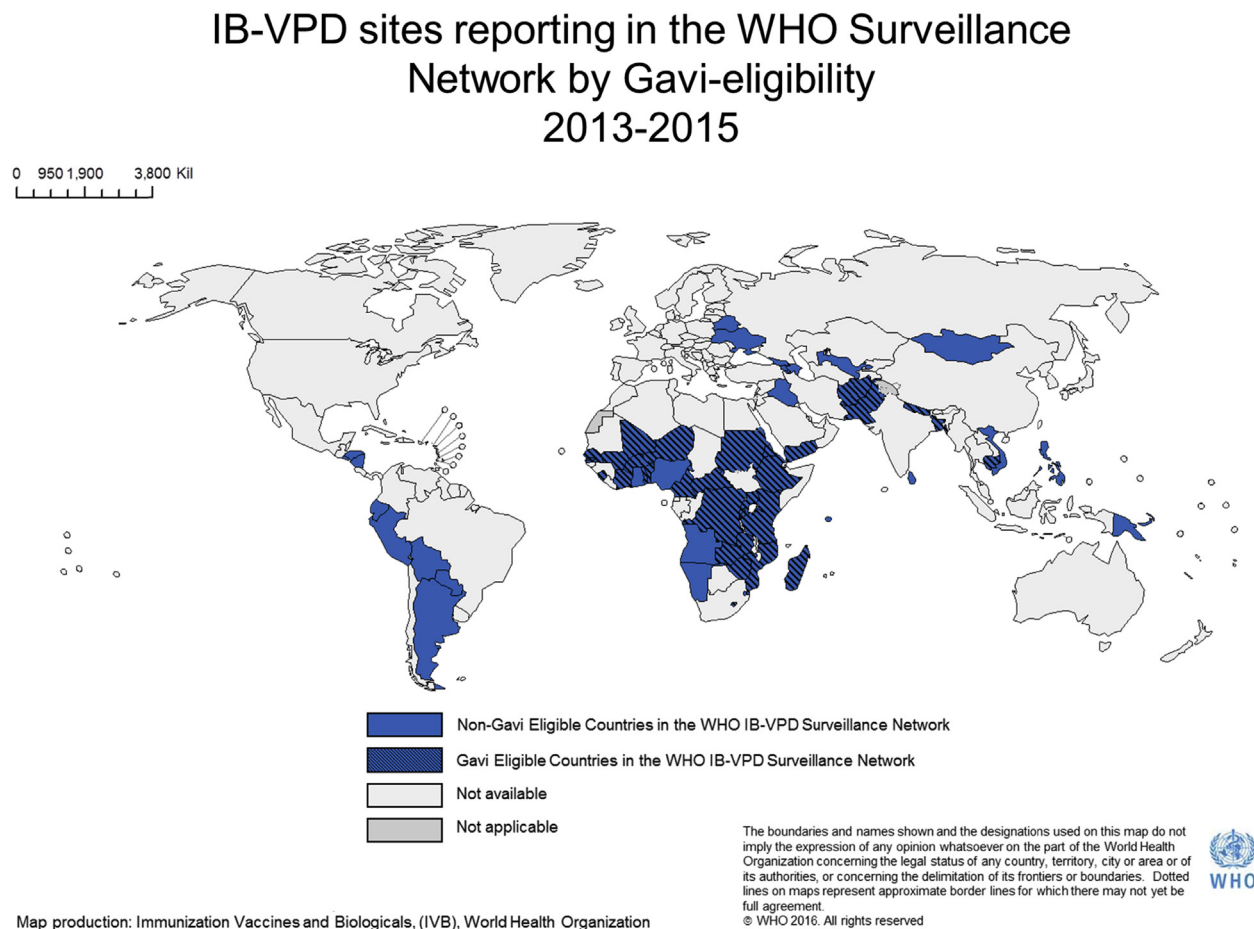
Active surveillance can have many approaches, including country-wide (e.g., for polio, measles, and rubella) or restricted to sentinel sites that capture cases within a demined catchment population. For example, as of 2015, the WHO–coordinated Global Invasive Bacterial Vaccine–Preventable Disease (IBVPD) Sentinel Site Surveillance Network is a system of more than 100 hospitals in more than 54 countries that conducts active surveillance for meningitis, pneumonia, and sepsis (Figure 1). Within this network, staff are engaged to work specifically on finding all cases meeting the case definition at the sites. Cases are enrolled into surveillance after they have been admitted to the medical facility. A case report form, filled out by the dedicated staff member, details their clinical symptoms. Laboratory testing is done at the hospital for initial diagnosis or at a national or regional reference laboratory to monitor for trends in culture positivity and serotype/serogroup incidence. These data

are reported to the Ministry of Health and WHO. Data are analyzed to look at trends of disease, including pre- and postintroduction of vaccine. Other diseases that have globally coordinated sentinel surveillance networks include rotavirus, influenza, and congenital rubella syndrome.

Surveillance for some diseases can be a mixture of passive and active surveillance wherein passive surveillance is complemented by active surveillance to investigate outbreak signals detected through passive surveillance. For example, surveillance for Ebola virus disease is ongoing throughout the year as it is a notifiable disease for many countries and globally. During an outbreak, active case finding in the community is enacted to find symptomatic patients as well as contact tracing to find those at risk for developing the disease.

Identifying Cases in Medical Facilities and the Community

Choosing where to conduct surveillance is based on a number of considerations: How severe is the disease and how does it present? How important is it to find every single case? How outbreak prone is the disease? Cases of infectious disease can be identified at medical facilities (hospitals and outpatient clinics) or in the community. The location of individuals enrolled into surveillance can vary based on clinical

IB-VPD sites reporting in the WHO Surveillance Network by Gavi-eligibility 2013-2015

Legend:
- Non-Gavi Eligible Countries in the WHO IB-VPD Surveillance Network
- Gavi Eligible Countries in the WHO IB-VPD Surveillance Network
- Not available
- Not applicable

The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.
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Map production: Immunization Vaccines and Biologicals, (IVB), World Health Organization

Figure 1   Map of sentinel surveillance site locations in the World Health Organization (WHO) Global Invasive Bacterial Vaccine-Preventable (IB-VPD) network reporting data from 2013 to 2015.

presentation of disease and access to health care. More severe cases of disease can often be identified at hospitals. Hospitalized cases are those that are severe enough to be admitted to the hospital for treatment and have the resources to seek care. Hospitalized cases can be enrolled prospectively or retrospectively when a case report form is filled out based on their medical chart. Identifying cases in hospitals can be easier than identifying cases in the community, but the cases may only represent a small proportion of cases and miss cases that do not seek health care. An example of hospital-based surveillance is severe acute respiratory illness (SARI) surveillance for influenza. For diseases like Ebola, where fear in the community might prevent cases from going to seek health care, hospital surveillance would be insufficient alone. Individuals with milder cases of disease may also seek medical care, such as at outpatient clinics, so surveillance may be conducted at medical facilities outside of hospitals, such as with influenza-like illness (ILI) surveillance.

Some cases of disease are so mild or the patient's situation is such that they will not be able to seek care at medical facilities. In that case, community-based surveillance can monitor disease outside of health facilities, such as at schools, homes, traditional medicine practitioners, and other community facilities. This type of surveillance aims to capture cases beyond those that are admitted to a health facility, therefore enrolling a wide range of disease severity and access to medical care. Community-based surveillance is useful for surveying diseases targeted for eradication because all cases must be traced and is not limited to those severe enough to be admitted to a hospital or those that have access to a health-care facility. Acute flaccid paralysis (AFP) surveillance is an active surveillance network that aims to identify every case of polio, which is currently targeted for eradication. Suspect cases are sought in the community and at health facilities to identify any unreported cases. This type of surveillance was also a method used in the Ebola virus disease epidemic of 2014–15. Community members and volunteers would report individuals with symptoms meeting the case definition for Ebola, who would then be visited by health personnel for testing. Community-based surveillance was supplemented by contact tracing, where individuals who had been in contact with confirmed Ebola patients were sought out in the community and monitored for symptoms.

Sentinel versus Population-Based Surveillance

A sentinel surveillance site is a single or small number of health facilities that are responsible for collecting data on cases enrolled with the case definition under surveillance including global networks surveying for diarrhea or pneumonia. Most sentinel sites do not have a predefined catchment population (or denominator to calculate incidence), and therefore data at these sites are simply numbers of cases (numerators). Sentinel site surveillance provides useful epidemiological information on proportions caused by different pathogens, age distribution, and risk factors and could also be used for monitoring trends of hospitalized cases within a health facility if health-care patterns and population have been stable. Furthermore, these data may be used in case–control studies to assess

effectiveness of a vaccine or other preventive measures. Surveillance focused on one or a small number of surveillance sites often allows for gathering more data of higher quality.

In contrast, with population-based surveillance, every appropriate health facility reports on the predefined diseases with the goal of identifying all cases in a specific geographic area. Population-based surveillance can either represent the whole country (national) or a defined subnational population area. Since the population is defined, these surveillance sites can produce rates of disease (for example, incidence and mortality rates), which allows for comparison of rates of disease between other population-based surveillance sites. Population-based surveillance is more costly than sentinel site surveillance, but produces more generalizable data on incidence of disease.

Case-Based versus Aggregated Surveillance

Aggregate surveillance data can exist in a variety of forms, but the main feature is that it lacks detailed information on specific cases. Aggregate data typically include the number of cases (for example, number of suspect and confirmed neonatal tetanus cases, or by age group) for a specific region and time period. This information can monitor the number of cases but lacks the individual-level data required for specific analyses. An example of this is the Integrated Disease Surveillance and Response (IDSR) system which asks clinicians to report the number of cases of specific diseases.

Case-based surveillance refers to surveillance systems that collect information about each case at the individual level. This type of surveillance system has a case investigation form where information can be gathered from the patient or their family members, their medical records, and their laboratory records. At a minimum, more detailed information on person (who is infected), place (where they live, where they might have been infected), and time (when they became ill) is collected. A line list from this investigation form is created and reported up their normal reporting channels. In some scenarios, a case-based surveillance system might transition to aggregate as the number of cases becomes large as it overwhelms the system, like what happened during the 2009 H1N1 outbreak. In contrast, an aggregate surveillance system might become case-based temporarily in an outbreak to understand more of the epidemiology of the disease. Certain diseases, such as polio and measles, are recommended to be case-based.

Measles surveillance has seen a movement away from aggregate and toward case-based surveillance (WHO, 2003). Initially, when the United Nations (UN) development goals were established in 1990, measles was endemic in many countries, and mortality reduction was the primary goal. Given this, aggregate data were the most feasible approach and were conducted in most countries. By 2016, all six WHO regions have measles elimination goals. As measles has moved away from control and toward elimination, case-based surveillance is needed to ensure every case is reported and investigated. When disease was endemic, case-based surveillance would quickly be overwhelmed given the time and resources, but as countries have fewer and fewer cases, it is relatively easier to conduct an investigation on every single case. WHO

recommends the type of data to be collected in an investigation. One key advantage of case-based surveillance is that it allows one to analyze which age cohorts are being infected and their individual vaccination status to help to target vaccination efforts and close existing immunity gaps.

Syndromic (Clinical) versus Laboratory-Confirmed Surveillance Case Definitions

Surveillance networks identify and enroll cases that meet a specific case definition. Case definitions have three essential components: person, place, and time. Case definitions vary in sensitivity and specificity. Sensitive case definitions are more inclusive, are less likely to miss cases, but will include patients that do not have the disease. Specific case definitions have stricter criteria and exclude more patients that do not have the disease but can also miss patients with milder or atypical disease presentations. Both sensitive and specific case definitions can be used in infectious disease surveillance depending on the goals of surveillance. For example, sensitive case definitions may be preferred if it is important not to miss cases. In general, case definitions should be as sensitive and specific as possible. However, since a highly sensitive and specific case definition is not always possible, it is important that the case definition is at least applied systematically and consistently over the surveillance period.

Syndromic surveillance involves monitoring cases that meet a clinical case definition for the disease under surveillance, typically without laboratory confirmation (Henning, 2004). This allows for rapid identification of a cluster of cases that might warrant further investigation. An example of syndromic surveillance includes acute fever/rash surveillance in many countries, which is used to monitor measles and rubella. The fever and rash could be due to a multitude of causes, and if there is an increase in the number of fever/rash cases reported, this could indicate an outbreak. As field investigations are ongoing, laboratory testing can be performed on some or all of the cases identified by syndromic surveillance to determine the etiology. In the acute fever/rash surveillance system, laboratory specimens might be collected to undergo testing for measles and rubella. A well-established global WHO-coordinated measles laboratory network provides support to monitoring measles cases and provide genotype information globally. Syndromic surveillance case definitions can be used in emergency or outbreak situations as an alert system to identify suspect cases that meet a broad case definition to then be further investigated. During the Ebola outbreak in 2014–15, airport security was increased to identify people with a fever and a history of travel to an Ebola-affected country in order to stop the disease from traveling between countries.

In contrast, some surveillance case definitions are based on confirmed cases in a laboratory where the etiologic agent can be identified through a variety of laboratory tests (e.g., serology testing, bacterial culture, or molecular diagnostics) or at the bedside with well-validated commercial rapid diagnostic tests (e.g., malaria and *Streptococcus pneumoniae*). As an example, virologic influenza surveillance networks use laboratory-confirmed influenza to determine the circulating strains to provide information for vaccine composition. A critical

objective of laboratory-based surveillance is to monitor for emerging drug resistance in pathogens or shifts in serotype distribution.

Cases meeting a suspect case definition (a sensitive case definition) may undergo laboratory testing leading to a more specific case definition. For example, the case definition for suspect meningitis as part of the WHO Invasive Bacterial Vaccine-Preventable Disease network is very sensitive: a hospitalized patient at a surveillance hospital with sudden onset of fever and at least one meningeal sign during the surveillance period. After being enrolled into surveillance, additional clinical and laboratory information can reclassify a patient as having probable bacterial meningitis (namely having abnormal white cell count, protein or glucose levels in cerebrospinal fluid). This definition has a greater specificity but lower sensitivity. The most specific meningitis definition is confirmed meningitis by polymerase chain reaction assay or other laboratory test. This definition may lose some sensitivity because confirmatory tests can have false negatives, especially in areas with high antibiotic usage.

Zoonotic Surveillance

Zoonotic diseases cause disease in humans and can be challenging to control since both animals and humans can be hosts. Many zoonotic diseases of public health importance are covered in other articles of this encyclopedia, including West Nile Virus, avian influenza, Ebola (and other hemorrhagic fevers), Lyme disease, SARS, Nipah virus, and rabies. Historically, zoonotic and human disease surveillance existed separately, but there is a push to harmonize these systems to improve surveillance for diseases affecting both populations. Illness in one species might be a harbinger of illness in humans, and an integrated comprehensive surveillance system can help identify potential disease transmission that might be ongoing. For example, surveillance for *Borrelia burgdorferi*, the causative agent of Lyme disease, in the tick population can help public health authorities determine proper interventions to decrease the transmission from ticks to humans. One Health emphasizes the link of human health to the surrounding environment and animals. One of the mission statements of One Health is to improve the lives of all species by harmonizing both animal and human disease surveillance and control efforts. International organizations participating in One Health include WHO, the UN Food and Agricultural Organization, and the World Organization for Animal Health.

Serosurveillance

Serosurveillance involves the use of blood specimens to determine the burden of disease or immunity gaps in a population. Serosurveillance is frequently done as a periodic survey for multiple diseases of interest simultaneously. However, serosurveillance cannot provide information in a timely manner; thus an outbreak might have occurred that is discovered by serosurveillance, but it might be potentially too late for an intervention to decrease disease transmission. Serosurveillance is sometimes the only type of surveillance conducted for an infectious disease. For example, hepatitis B is frequently asymptomatic in children, making evaluating the impact of vaccination efforts extremely challenging (WHO, 2011). The standard has

become to perform serosurveillance among cohorts of vaccinated children to identify the burden of disease and determine the impact of vaccination efforts. In some countries, national health surveys, such as the National Health and Nutrition Examination Survey (NHANES) and Malaria Indicator Surveys, are conducted periodically and include a serologic component, allowing one to monitor trends in diseases and immunity over time. For example, NHANES includes data on hepatitis B, C, and D antibodies.

Adverse Events Following Immunization Surveillance

Adverse events following immunization (AEFI) surveillance is a critical component of ensuring vaccine safety in the populations where the vaccines are being used. Surveillance often begins at the health facility level, where health workers are trained to recognize adverse events from immunizations, and is reported to national regulatory agencies and WHO. This surveillance is critical for investigating problems that could occur with bad lots of vaccines and mishandling of vaccines in the cold chain (improper storage) which can contribute to the public perception of the vaccine program.

Innovative Technology Strategies for Surveillance

Technology is increasing the availability of data on health that can be used for infectious disease surveillance, including sources that go beyond that of traditional passive or active surveillance systems. New sources of data include mobile data, electronic health records, and social media. These aggregate sources and the speed at which they can be compiled are referred to as 'big data' (Wyber et al., 2015). These sources of data can provide more real-time information to help mitigate outbreaks or improve the health of a population.

In 2008, Google started a venture called 'Google flu' which was an algorithm tracking global search habits (such as search engine queries for 'influenza') with the hope that it could act as a real-time syndromic surveillance system. It was one of the first 'nowcasting' surveillance technologies and was able to predict influenza disease with some accuracy, close to the US CDC influenza reports based on laboratory-confirmed influenza surveillance. However, after a couple of years, it was found to overpredict the number of influenza cases given the generic case definition used. The system is no longer active, but is used to help groups develop newer public health analytics.

The use of mobile technology to improve systems is an important area for public health (also referred to as m-health) and has a growing use for surveillance. Mobile data can monitor the movement of people during an outbreak, and this information can allow health officials to better predict where a given disease will spread. The UN Pulse Project supports infectious disease mapping in Kampala, Uganda, using m-health (UN Global Pulse, 2015). In 2015, there was a typhoid outbreak in Uganda. The Pulse Lab in Kampala provided mobile data to complement data which the Ministry of Health collected on cases. These data sources combined allowed better visualization of the outbreak and where clusters of infections were happening and therefore permitted improved mobilization of resources to respond to the outbreak.

Flowminder is another organization developing the use of mobile technology in outbreak situations. It currently has projects supporting monitoring the spatial patterns of individuals during outbreaks using data from mobile phones. During a cholera outbreak in Haiti in 2010, researchers from Flowminder mapped the movement of people using anonymous data from mobile usage from the affected areas (Bengtsson et al., 2015). Following the outbreak, the data were analyzed, and it was shown that this was an effective way of mapping the spread of the outbreak.

Global and Regional Surveillance Partnerships for Disease Control

Many partnerships between academic, programmatic, and global organizations exist to facilitate ongoing infectious disease surveillance and promote global health security. Partnerships can take different forms and often include providing technical and operational support and resources to facilitate ongoing surveillance. Some examples are as follows.

Integrated Disease Surveillance and Response

In 1998, the IDSR strategy was first drafted by the WHO Regional Office for Africa in order to harmonize existing surveillance networks (including AFP and neonatal tetanus) in the African region (WHO, 2010). The strategy aims to integrate surveillance being done at the community, health facility, district, and national level to improve the data collected and to conserve resources. IDSR includes standard case definitions and protocols and involves collecting only data necessary for disease control, often aggregated data. This helps to decrease the work burden at all levels on health staff, is more efficient, and costs less than nonintegrated surveillance. However, the challenge of integrated disease surveillance is that sometimes more information is needed than is readily available to target intervention activities.

Global Outbreak and Response Network

The Global Outbreak and Response Network (GOARN) is a WHO-coordinated network comprised of over 600 partners worldwide, including government, technical, and academic institutions involved in epidemic surveillance. The purpose of GOARN is to coordinate a rapid response to international disease emergencies through deployment of resources to the affected countries. GOARN coordinates a multidisciplinary team comprising clinicians, epidemiologists, social mobilization, and communications experts.

GeoSentinel

The increase in international travel is an important risk factor in the spread of infectious diseases. Travelers can contract many infectious diseases, from common travelers' diarrhea to more serious conditions such as Ebola. This can pose a serious public health risk if conditions are right for an outbreak or when novel pathogens are introduced into a naïve (not vaccinated or without protective antibodies) community. GeoSentinel is a global network of clinics assessing travelers' and

migrants' health for illnesses acquired while abroad (Leder et al., 2013). This network of clinics confirms and registers cases of infectious diseases acquired while traveling. This surveillance information is critical for tracking the movement of diseases and informing guidelines for travel medicine.

Disseminating Infectious Disease Surveillance Information

Surveillance is an action-oriented public health tool. Time lags in surveillance can affect outcomes if there is not a rapid response with interventions. Surveillance information can be used at the global, regional, national, local, and individual levels. New technologies are being developed to assist with more real-time data dissemination.

Periodic Dissemination Tools

Surveillance bulletins and reports are a frequently used method for disseminating surveillance information. Many surveillance networks use them to send information to stakeholders and partners involved with the surveillance. These can be frequent (weekly or monthly reports) or more infrequent such as annual or biannual surveillance bulletins. These normally include case counts for the disease under surveillance or detection of new outbreaks.

The scientific literature (peer- and non-peer-reviewed publications) and scientific conferences are also important venues for disseminating surveillance data. The audience for publications can be much wider than bulletins since they are accessible by a wide range of individuals. There can be a long lag-time between data generation and publication. These modes of communication are critical for improving the wealth of available knowledge and advancing research, but are not timely enough to mobilize a response to an outbreak. The Morbidity and Mortality Weekly Report (MMWR) from CDC and the Weekly Epidemiological Record (WER) from WHO are two examples of periodic, non-peer-reviewed dissemination tools. The MMWR publishes an annual list of notifiable diseases using weekly data on the CDC surveillance systems. The MMWR publishes weekly reports for outbreaks and case reports for diseases under the International Health Regulations.

Ongoing, Real-Time Dissemination Tools

With the advance of social media and the Internet, there have been innovative strategies for more quickly disseminating surveillance information for rapid public health intervention. For example, the Program for Monitoring Emerging Diseases (ProMED) is a popular tool run by the International Society for Infectious Diseases. It consolidates and verifies reports from media, observers, and news and disseminates via email and their website. They have a large audience since their information is free and easily available on the Internet. They act as an important early warning of outbreaks to facilitate public health preparedness.

Online platforms are creating innovative ways of displaying the surveillance data that are collected. An online platform called HealthMap run by Boston Children's hospital is one example (Figure 2). Reports of disease cases come from a series of vetted online sources (including ProMED, WHO, and online news outlets) and are mapped on an interactive interface allowing users to view the geographic distribution of multiple diseases. Physicians and individuals can use HealthMap to identify diseases occurring close to them or their travel destination.

Other tools include the Health Alert Network (HAN) at CDC, which is used for quickly disseminating confirmed disease reports and information to medical and public health professionals at a national level. HAN disseminates four types of information: (1) health alerts (where an action required); (2) health advisories (information on health events where no action required), (3) health updates (information on given events); and (4) general public health information. In February 2016, HAN released an official CDC health advisory on preventing sexual transmission of Zika virus after a confirmed sexually transmitted case in Texas.

Event-based surveillance entails monitoring cases and outbreaks of disease through formal and informal news and online reporting platforms. Traditional surveillance can miss many outbreaks or delay the opportunity to intervene. Event-based surveillance includes reports from the community, health facilities, universities as well as media and online sources in order to develop alerts of health situations that are developing. The data and reporting methods are much less structured than other surveillance, but allow for quick detection of events that need to be investigated.

Surveillance as a Platform for Research and Special Studies

Surveillance is in and of itself a critical tool for public health. Using an existing surveillance network as a platform for surveillance of additional diseases allows streamlining resources and can be a cost-effective measure to improve public health. For example, influenza surveillance is being leveraged to conduct surveillance for other respiratory viral diseases, such as respiratory syncytial virus. Additionally, the laboratory, clinical, and epidemiological capacity built to run a surveillance network can be utilized for other public health studies.

Vaccine Studies

Surveillance sites can be used as platforms for research and special studies. Since infectious disease surveillance sites often conduct surveillance for vaccine-preventable diseases, studies on vaccine effectiveness and vaccine impact can be built on the platform of surveillance. Vaccine impact studies can use surveillance to demonstrate reduction of disease after introducing an intervention such as a vaccine. These impact studies require baseline data before the vaccine was introduced in order to compare the postvaccine era to the prevaccine introduction disease incidence. Special studies that gather additional information may complement surveillance disease trends. Vaccine effectiveness studies evaluate the ability of a vaccine to control the disease in a real-world setting, which differs from vaccine efficacy studies where the vaccine impact is estimated in a controlled clinical situation. A good example of this is rotavirus diarrheal sentinel site surveillance, which has been used both to show the
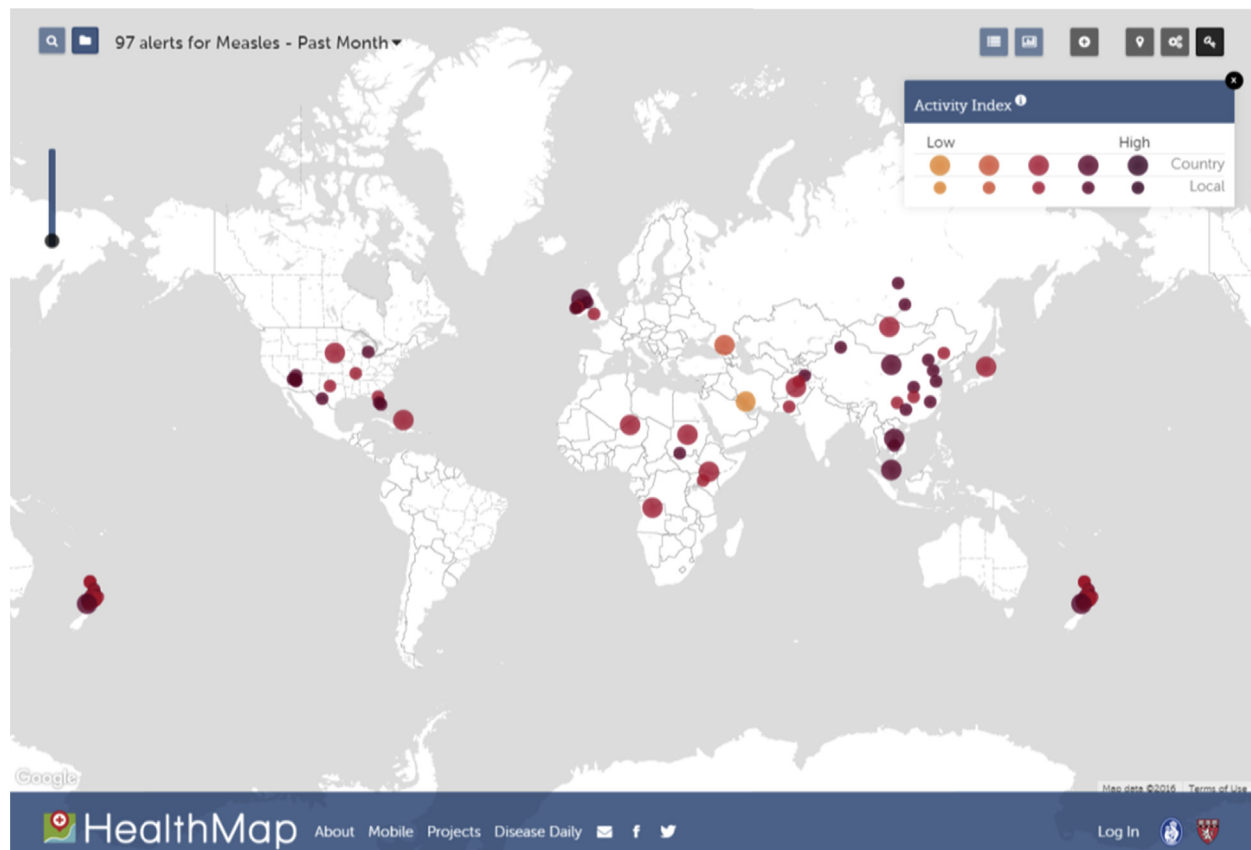
Figure 2 HealthMap displaying reported measles cases for the past month (June 2016), using reports from sources such as media outlets and ProMed newsletters.

decline in rotavirus disease among age groups vaccinated as part of routine immunization and has also been used as a platform to conduct vaccine effectiveness studies.

Burden of Disease Models

Estimating the burden of disease at the country or global level with epidemiological models can be a critical part of using surveillance data and advocacy for disease interventions. In many countries, surveillance data alone may not be sufficient to provide informative data for a specific disease for a number of reasons: surveillance data may not be available, there might not be laboratory confirmation, or the data necessary to answer a certain question may not have been collected. In these situations, models using local and nonlocal data can be very useful. In addition to data from one region being extrapolated to inform on the disease within that region, data from similar regions can also be used to fill in gaps where surveillance is missing. There are many global burden estimation projects updated regularly to give global prevalence and mortality estimates by different government, research, and academic groups for a number of diseases (for example, influenza, *S. pneumoniae*, and rotavirus). Burden estimation modeling can also be done on the national level using surveillance data collected locally. Surveillance data have been used in a model to extrapolate the burden of influenza-associated hospitalizations in South

Africa, Guatemala, and Kenya using local surveillance data from the country (Murray et al., 2015).

Acknowledgment

See also: Childhood Infectious Diseases: Overview; Ebola and Other Viral Hemorrhagic Fevers; Geographic Information Systems (GIS) in Public Health; Health-Care Delivery Systems; Influenza; Measles; Poliomyelitis; Surveillance of Disease: Overview.

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