Principles of public health surveillance

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Abstract

Surveillance is a core public health activity of all nations allowing collection of standard measurable information on the occurrence of diseases and disease risk factors. The product of surveillance, surveillance data, constitutes a standardised international language of public health. Like the personal health risk appraisal, in which information about an individual's health risk factors is combined to predict future health, surveillance data provide public health workers with an assessment of the health of the community. Though the term surveillance covers a variety of different specific activities, undertaken by different types of health workers and by people not in health fields, the ultimate goal of all public health surveillance is to support public health action as fully, as specifically, and as expeditiously as possible.

Introduction

The word 'surveillance' has more than one meaning in public health. The dictionary defines surveillance as 'a close watch [kept] over someone. . . also supervision' (Hong Kong Longman Group, 1984). This is not the type of surveillance that will be the subject of most of the following discussion, although it does have public health relevance. For example, it occasionally happens that when persons or groups are suspected of incubating infectious diseases, they are placed in isolation. Contact with others is temporarily prevented while such individuals are monitored for evidence of disease onset until a safe time has passed. For example, travellers exposed to Ebola fever have been isolated and placed under surveillance by public health officials after arrival in Western nations. Here, the purpose of surveillance is obviously to prevent introduction of disease into communities without it. This type of surveillance is an important, but usually not a major activity of public health.

Another definition of surveillance suggests that it is the systematic collection, analysis, interpretation and dissemination, in processed form, of data pertaining to the occurrence of specific diseases (Evans, 1982). This is a much better definition. It describes a public health activity that is universal, ongoing, and multidimensional. It rightly suggests the need for integration of effort. But it is perhaps too limited in confining itself to specific diseases. Is it not important to conduct surveillance for disease risk factors? This may be implied by the phrase 'pertaining to the occurrence of specific diseases', but it is also true that surveillance may be conducted for general risk factors related to many diseases, not just specific ones. Hypertension and smoking come to mind. Moreover, depending on how 'strict' one wishes to keep the definition of surveillance, we may conduct surveillance of population vital events such as births and deaths, of health itself, or of utilisation of health services.

A third definition, applied specifically to disease and health, adds another important element. This definition characterises public health surveillance as the 'collection of data, the collation of data, the analysis and interpretation of those data, the dissemination of the findings and the promotion of control and preventive action' (Tyler, personal communication). The new element in this definition is an active end product: after surveillance has been undertaken, there is the expectation that something will be done with the information obtained. In recent years, some controversy has arisen in the U.S. over separation of these afferent and efferent 'arms' of public health: specifically, as to whether surveillance, *per se* should be conceptualised and undertaken as a separate public health activity, divorced from public health action. In this discussion we will try to strengthen the importance of integrating surveillance and action by claiming surveillance should not be undertaken at all unless something (public health action) will be done with the information.

Historical perspectives on surveillance

From Hippocrates' theories . . .

The ancient Greeks did not conduct disease surveillance, but they seemed to have had a clear picture of some of the principles that underlie it. Hippocrates (c. 460 B.C. – c. 377 B.C.), considered the Father of Epidemiology as well as the Father of Medicine, undoubtedly had some quantitative sense of disease occurrence in the fifth century before Christ. He did not make line lists of cases, nor did he fill out monthly tally sheets, but he did recognise the importance of variations in disease occurrence by time, location, gender, age, occupation, etc. (Hippocrates, 1978). That is, he characterised diseases in person, place and time. In recording an epidemic seen during Hippocrates' lifetime, his contemporary, the Athenian general Thucydides, had sufficient appreciation of active disease surveillance to count denominators of persons at risk, numerators of affected persons, and to calculate attack rates and case fatality ratios (Thucydides, 1977). Apparently these 'modern' approaches were so intuitive, even to ancient Greek laymen like Thucydides, that they were not considered worth writing down as principles.

Surveillance should not be undertaken at all unless public health action can be done with the information.

A few centuries later, the Romans became expert at what we might call (colloquially) 'denominator surveillance', in distinction to 'numerator surveillance'. These terms are not real scientific terms, but terms that reflect, respectively, the epidemiologic argot of 'denominator data' and 'numerator data'. Many health measures of risk are derived by dividing numerators of new cases, or of current cases, by denominators of living persons – or better yet, of living persons actually at risk of getting the disease in question. We must generally conduct surveillance to find out not only how many people are in the numerator (e.g. morbidity, mortality), but also how many are in the denominator. A population census would come under the heading of 'denominator surveillance'. The Romans were skilled census takers, though not to derive health data or improve health advances in surveillance in the millennium following the Roman era, if they occurred at all, have been largely lost. It is not until the age of the Black Death (bubonic/pneumonic plague, which became pandemic in 1348), that public health surveillance again became prominent. European city fathers quickly recognised that plague was being introduced via seaports. Venice and Ragusa were among the first port cities to put all entering ships under quarantine, typically for about 30 days. Eventually, the 30 days were extended to 40 (the term quarantine comes from the Italian word *quaranta*, which means forty).

Early quarantine was an example of disease surveillance in the limited sense mentioned above: to isolate and monitor persons who might be incubating infectious diseases, for the purpose of preventing disease introductions into disease-free populations. Ships were forced to anchor off-shore, until city officials were assured that none on board were ill. Only then could the crew disembark and the cargo be unloaded. (Ironically, despite good intentions, quarantine failed as a public health measure because infected rats on board ship, rather than infectious crew members, brought plague into the port cities). It is of historical interest to note here that acceptance of surveillance as an infection control measure by 14th century city officials seems to implies a notion of contagion, which was not to be articulated in any comprehensive manner until 200 years later, and not fully accepted for over 500 years.

. . . to the modern tools of epidemiology

Modern disease surveillance could not be undertaken until progress was made in two areas: systematic recording of population events, and better understanding of disease etiology. As European nations emerged from feudal states, systematic recording of vital events (births, marriages, deaths) became nearly universal, at first by churches, and later by governments themselves. By the 17th century local registries of vital events were commonplace in Europe. England introduced a surveillance system of weekly 'Bills of Mortality' (early death certificates), to be completed by each parish priest, in 1532, and Sweden followed suit with a registration system in 1608. Civil, as opposed to ecclesiastical, surveillance systems for vital events followed rapidly in Europe, especially in the Scandinavian countries, e.g. Finland (1628), Denmark (1646), and Norway (1685). The United States and most Pacific and Asian nations were extreme latecomers to vital registration, most not having well developed systems until the late 19th or early 20th centuries.

Epidemiologists often trace their professional origins to the avocational efforts of English tradesman John Graunt (1620–1674). In 1662, Graunt examined the Bills of Mortality to make inferences about the distribution and determinants of death in large populations, including London. In doing so, he distinguished for the first time acute and chronic diseases, and invented life table methods. Thomas Short (1690–1772) advanced Graunt's analyses in 1750 by studying geographic variation in British mortality.

Understanding disease etiology was more problematic. Before the theory of contagion became universally accepted (around 1900), miasmatism – belief that epidemic diseases result from climatic conditions that poison the air – dominated European thought. The contagion theory, proposed in ancient Greece but disbelieved for two millennia, finally began to be accepted around the same time that population data became increasingly sophisticated, supporting the development of surveillance as we know it today.

Populist public health notions, evolving in France in the late 1700s, coupled with more authoritarian public health notions in the German-speaking states, were crystallised by the industrial revolution that exploded in the first half of the 19th century. Especially in England, sanitary movements developed into systems of municipal public health, and these systems needed not only good census and vital events data, but also good morbidity data. Increasingly, such data became available.

The century bracketed by roughly 1790–1890 saw the growth, development, and sophistication of virtually all of the basic modern principles of surveillance, including attempts to standardise reporting and coding of causes of death. In the 1790s, London physician Robert Willan (1757–1812) was reporting weekly cases of specific epidemic diseases and complaining that his 'numerator' contributions were not showing up in official reports (Willan, 1801). Creation of a national mortality reporting system in 1837 revolutionised understanding of disease occurrence in Britain. Data on cause-specific mortality created a greater desire for data on cause-specific morbidity. A century after Willan's death, morbidity data systems had been greatly improved: for some well-characterised diseases, they were as complete and accurate as those in use today.

In the intervening century, concepts of public health that had grown and developed included the following: an appreciation of 'laws' of disease and mortality, medical statistics, the science of epidemiology, and articulation – by Jacob Henle (1809–1885) – of the principles for establishing infectious disease etiology ('Koch's postulates'). John Snow (1813–1858), Queen Victoria's anaesthesiologist, had scientifically demonstrated contagion and, in the process, had introduced analytic epidemiology. William Farr (1807–1883), Snow's friend, had formulated the first formal principles of disease surveillance. In establishing the London Epidemiological Society in 1849, Farr, Snow, and a small group of Londoners introduced a dramatic perceptual breakthrough: that data obtained from surveillance of diseases could produce *scientific* information leading to their prevention and control.

This was a powerful realisation whose appeal was better appreciated initially by municipal authorities than by scientists. The last half of the 19th century became an era of strong municipal public health; it was succeeded by a period (roughly 1900–1945), in which national public health systems were developed and strengthened, to be succeeded, in turn, by the current era (1945 to the present) in which international public health surveillance is slowly beginning to expand and grow.

It is interesting to observe that surveillance seems to have led the rest of public health through its successive eras of municipal, national, and international development. A good example from the current era is the way in which international surveillance of smallpox led to international cooperation in its eradication. Hopefully, eradication of polioviruses will follow in this decade or the next. For most of the world, only international efforts in HIV control, now confined largely to surveillance networking, can hope to prevent the deaths of millions more people from AIDS.

Modern surveillance is a core public health activity integrated into all levels of public health, from the local to the international, providing scientific links between disease recognition and disease control within populations.

Types of surveillance

We have already noted two general types of surveillance that have been referred to, colloquially, as 'numerator surveillance' and 'denominator surveillance'. When we use these terms, we are thinking about health event occurrence rates (e.g. disease rates) which must always have the same three elements: (1) the number of people who have, or who get the health event, (2) the number of people who are 'at risk' of having or getting the health event, and (3) a unit of time.

The two most common examples of health event rates are disease incidence rates and disease prevalence rates. In arriving at disease incidence rates, for example, we typically divide a numerator containing all persons in the population under study who get the disease, by a denominator containing all persons who could have gotten the disease (including those who actually did get it, and those who did not), and we multiply the result by some unit of time, such as 'per month', or 'during 1995'. If our population of interest is as large as a city, it is clear that we must have surveillance data concerning not only the number of people in the city who got the disease, but also on the number of people at risk. In short, we must have 'numerator' and 'denominator' surveillance data.

Surveillance seems to have led the rest of public health through its national and international development.

In practice, denominator data are usually easier to obtain by census, as actively undertaken in the community, or as estimated by statistical projections from prior censuses. 'Denominator surveillance' is thus not always considered a public health activity, and it is not dealt with in detail in this review. On the contrary, 'Numerator surveillance' constitutes a core activity of public health, and is categorised in several different ways: for example, case vs. population surveillance, active vs. passive surveillance, and sentinel vs. non-sentinel surveillance. Each of these will be discussed below.

Case surveillance

As already noted, the term 'surveillance' has multiple meanings in public health. One meaning refers not to populations, the usual clientele of public health, but to individuals or small groups of individuals within populations. In an example referred to above, we might say we are 'putting Mr Smith under surveillance while we attempt to rule out Ebola fever'. Some types of contact tracing, e.g. following up on venereal disease exposures, represent similar public health activities. These are examples of case surveillance, and while they are legitimate and important public health activities, they will not be discussed in detail here. We should note that case surveillance is always *active* rather than *passive*, meaning that this type of surveillance requires specific actions of public health workers, as opposed to merely receiving reports about occurrences of a disease and adding them to a larger data set made up of similar reports.

Population surveillance

More commonly, public health workers are concerned about surveillance in populations such as villages, cities, countries, districts, provinces, states, or nations. As above, such surveillance may be either *active* or *passive*. Departments and ministries of health normally rely on passive surveillance as their core surveillance activity. Passive surveillance data may be received by informal means such as phone calls, letters, newspaper reports, complaints, etc. But they come more often from passive surveillance systems.

Surveillance systems are systems set up for the express purpose of obtaining regular information on the occurrence of one or more diseases. A well known type of surveillance system found in most countries requires either physicians, other health providers, diagnostic laboratories, or all of these, to report all new cases of any of the diseases on a list of notifiable diseases. Most diseases on such a list are either infectious or of unknown etiology, although chronic, genetic, nutritional or occupational conditions are sometimes added.

The notifiable disease systems are passive in the sense that patients are being seen anyway, and their diseases are being diagnosed anyway. The surveillance system merely collects and centralises information that has been produced for other important purposes, especially for diagnosis and treatment. A second example of a passive surveillance system is the United States weekly influenza surveillance system. In this system, 121 pre-selected American cities report to the U.S. Centers for Disease Control and Prevention (CDC) on a weekly basis during the influenza season, all recorded deaths listing either influenza, pneumonia, or both, on the death certificate. This P&I mortality system does not intend to capture many influenza diagnoses – in fact, most cases of pneumonia and many cases of influenza listed on death certificates are NOT attributable to influenza. This passive surveillance system seeks, instead, to identify national influenza epidemics based upon the observation that only during epidemic periods do weekly P&I deaths rise statistically above background occurrence rates. Detection of a national epidemic, which occurs annually in the U.S. and most other countries, allows a prompt response to physicians and the public.

The purpose of sentinel surveillance is early warning for diseases for which public health actions may prevent epidemic spread.

Active surveillance, in distinction to the passive examples cited above, requires the physical activity of public health workers. Some ministries and departments of health conduct active surveillance, but it is more often associated with university or industry research efforts. Although active surveillance systems may be set up, most active surveillance data come from distinct studies that begin and end within a reasonably short time frame. It is thus helpful to think of *active surveillance studies*, on the one hand, and *passive surveillance systems* on the other. Examples of active surveillance studies might include study of a random sample of persons of all ages on a Pacific island to determine the prevalence rate of hepatitis B surface antigen (HBsAg) carriage, or a study of neutralising antibodies to each of the four dengue serotypes in a random sample of Hong

Kong residents. Serosurveillance, the practice of measuring antibodies to microorganisms of interest in representative population samples, is a traditional form of active surveillance. A special form of active surveillance, referred to as *sentinel surveillance*, is discussed below. The purpose of sentinel surveillance is early warning, and it is generally only undertaken for diseases that are important, and for which public health actions may prevent or limit epidemic spread. Another form of active surveillance, called screening, is generally undertaken to identify individuals with, or at risk for, specific diseases or conditions that can be prevented or treated (e.g. hypertension, tuberculosis).

Public health population surveillance

There are four generally recognised categories of public health population surveillance. These four categories reflect different activities, usually undertaken by different people, to provide data to be used for different purposes. But each of them represents, directly or indirectly, disease or other health event occurrence or the potential for disease occurrence. The four categories are: (1) vital events – mostly mortality – surveillance, (2) morbidity surveillance, (3) exposure/risk factor surveillance, and (4) health care use surveillance.

Vital events (mortality) surveillance

Mortality surveillance is most useful in wealthy developed nations where all deaths are recognised and recorded, and where diagnoses are relatively accurate. However, as all public health professionals are aware, death certificate data from even the most advanced nations are highly erroneous, especially for chronic and lifestyle-associated conditions. Mortality data are most relevant to diseases that are either uniformly or highly fatal (rabies, HIV infection), that are uncommonly missed or misdiagnosed, that are of chronic or of multifactorial etiology (e.g. cancers, heart attack, diabetes), or that may be amenable to primary, secondary, or tertiary prevention. Sources of mortality data include vital records (death certificates, fetal death certificates), data from coroners and medical examiners, hospital 'discharge' data, police data (e.g. traffic accidents, drownings), etc.

Edgar Lee Master's *Spoon River Anthology*, a set of poems from fictional tombstones in a single cemetery, might be considered a culturally-refined example of mortality data (Masters, 1928). In recent years, historical epidemiologists have actually learned much about disease occurrence in previous centuries by analysing burial records for excess burials as a marker for epidemic occurrence (Hope-Simpson, 1986). Among other vital events, births themselves may be treated as population surveillance data. That most births produce normal infants lends a positive dimension to surveillance, so frequently associated with frightening diseases. Birth certificates and other birth event data may nevertheless be surveyed for unfortunate outcomes such as major birth defects.

Morbidity surveillance

Morbidity surveillance, a major activity of most health departments and ministries, seeks to detect the occurence of specific conditions that may be fatal. In developed nations, morbidity data for infectious diseases generally come from passive morbidity surveillance systems (notifiable disease systems). The list of notifiable diseases often exceeds 50, and may approach 100. What a disease has to 'do' to get on a notifiable diseases list is discussed below. Other sources of morbidity data include hospitals (e.g., discharge data, infection control data), clinics, physicians' offices, laboratories, schools, industries, the military. Data can be actively obtained from community surveys, serosurveys, or surveys of indirect indicators of disease occurrence (e.g. pharmacy prescriptions of diphenoxylate as an indicator of gastrointestinal disease occurrence, or of levodopa/carboxydopa as an indicator of Parkinson's disease).

Exposure/risk factor surveillance

Exposure/risk factor data usually come from active surveillance studies, or from screening programmes. Exposure surveillance is conducted either to identify population risk by studying past disease experience (e.g. dengue serosurveys), to identify persons with, or at risk for disease (e.g. screening, such as screening for tuberculin positivity or HBsAg positivity, or genetic screening for sickle trait) to gain indirect information on actual disease occurrence by proxy (e.g. pharmacy surveillance for disease-specific medications, as cited above). This type of surveillance can be useful for early warning (e.g. serologic surveys of sentinel pigs for infection with Japanese encephalitis virus, of *Aedes* mosquito pools for dengue virus positivity and of neighborhoods for *Aedes* larval indices, for hazards exposures in environmental health), or for understanding vector and reservoir dynamics (e.g. studies of wild animals in areas that are not rabies-free). Long-term 'banking' of serums to study diseases that may emerge in the future is an important public health surveillance activity that has been poorly-supported in recent years.

Utilisation surveillance

A final category of surveillance, surveillance of health services provided or utilised, may yield indirect measures of disease occurrence (e.g. hospital admissions, hospital censuses, hospital bed vacancies) or disease severity (e.g. utilisation of programmes for disabled children), and also obviously assists health officials in planning for and securing funds for delivery of primary services.

Why do we surveil?

That surveillance activities constitute such a large part of public health practice must be a clue to their importance. We have actually already examined (above) many of the reasons why we surveil ('surveil' is the correct, if rarely used, verb form of 'surveillance'). The following list was suggested by some of the author's public health experiences surveillance data. Why do we surveil? There are many reasons.

1. Case finding. Example: one of the reasons we conduct surveillance for HBsAg positivity is to find positive persons who may need to be monitored for liver cancer risk, counselled about actions to reduce transmission, or, in the case of pregnant women, to intervene medically to prevent transmission to their newborns.

2. To get the flat part of the epidemic curve. Example: in order to identify an increase in P&I mortality during the influenza season, we need to monitor P&I mortality continually, especially during the non-influenza seasons of late spring through early fall. As epidemics are defined as increases in occurence beyond background level, they cannot be identified unless the background level is known.

3. To identify epidemics and document their termination. Example: related to the item immediately above, once the background rate of occurrence is established, epidemics can be identified and action taken. A good example of this is recognition in 1981 of an epidemic of immunosuppression (later found to be caused by a new disease, AIDS), based on an epidemic of requests to CDC for the anti-*Pneumocystis* drug pentamidine.

Identification of secular trends in the occurrence of many diseases allows us to predict epidemics.

4. To monitor disease trends. Example: in the pre-vaccine era, measles was characterised as being epidemic in large populations in cyclic patterns of winter increases occurring every two to three years, while rubella exhibited epidemic cyclicity at six- to seven-year intervals. Identification of secular trends in the occurrence of many diseases allows us to predict epidemics, and also increases epidemiologic understanding of diseases.

5. *Surveillance-response triggering*. Example: detection of increasing incidence of tuberculosis in the U.S. is allowing national, state, and local health agencies to revitalise tuberculosis programmes to find and treat persons with inactive, active, and drug-resistant tuberculosis.

6. Determining incidence and prevalence rates. Example: identifying 200 new cases of tuberculosis per year in a state of one million persons allows calculation of a crude incidence rate of 20 cases per 100,000 persons per year, a high rate of occurence compared with many other states.

7. To define the magnitude of the problem. Example: in the tuberculosis example above, incidence determination allows state health officials to compare the magnitude of their tuberculosis problem with those of other states, with their own data from earlier times (e.g. the pre-treatment era that ended in the early 1950s), or to compare tuberculosis incidence with the incidence of other important diseases that require public health action.

8. Planning and resource allocation. Example: identification and characterisation of epidemic tuberculosis allows health planners to increase tuberculosis control staff and to submit budget requests to fund expanded activities. It allows health officials to prioritise health problems and commit limited resources more appropriately.

9. To provide descriptive epidemiology (person, place and time). Example: in one American city, studies showed that newly identified cases of tuberculosis tended to be found in middle-aged HIV-positive men in a blighted inner city area where drug abuse was rampant.

10. To generate research information. Example: much of the early information on Kawasaki disease, a condition of unknown etiology, arose from national surveillance in the U.S., which identified outbreaks and case reports; the case reports were combined and compared to create a more specific picture of this allegedly-rare syndrome. (Ironically, surveillance data gradually revealed that Kawasaki disease is relatively common).

11. To identify new diseases. Examples: disease surveillance systems for measles have routinely identified epidemic dengue in areas where it is not expected to occur. Hantavirus pulmonary syndrome, a previously unrecognised syndrome, was discovered through surveillance systems that identified rare cases of unexplained deaths dispersed across wide geographic areas. Acute hemorrhagic conjunctivitis (apparently a genuinely-new disease caused by the emergence of two different enteroviruses around 1970, in Africa and in Asia) was identified by surveillance systems.

12. To identify risk factors and obtain clues to disease etiology. Example: the etiology of Lyme disease was suggested by surveillance data on geographic occurrence that corresponded to vector tick and reservoir deer and mice distributions. The causative agent was later identified in ticks.

Lists of notifiable diseases have tended to expand in the past three decades.

13. To assure the public. Example: during the hantavirus pulmonary syndrome outbreak in the Southwestern U.S., in the summer of 1993, surveillance data were regularly presented to the press and public to provide assurance about the nature, scope, and extent of the epidemic.

14. To obtain data for grants and reports. Example: this use is so familiar to everyone in public health that no examples are needed. Of course, writing reports and grants is not a reason that surveillance should be undertaken; it just seems that way to those who have to write them.

15. To practice vigilance. Example: to recognise emerging infectious diseases, surveillance systems must be ‘up and running’, and the people who run them must be alert. The word ‘practice’ is used not in the sense of ‘to conduct’ or ‘to carry out’, but in the literal sense of ‘practicing’, as in practicing the piano in order to play Ives’ Second Sonata. Public health vigilance is a skill that must be continually practiced if it is to be successful.

How are the diseases selected for surveillance ?

Lists of notifiable diseases have tended to expand in the past three decades, as more diseases have been discovered, and more effective public health programmes have been set up to deal with many of the old and new. Some official organisations, such as the U.S. Association of State and Territorial Epidemiologists, have worked against mission creep, realising that in public health, mission creep is rarely matched by budget creep. Many epidemiologists dream about shorter lists of notifiable diseases; this, coupled with concern about emerging infectious diseases, is prompting a closer look at some of those that emerged and devolved long ago, and real attempts at streamlining (CDC, 1991). In this climate, it is appropriate to ask for what diseases should precious public health resources – personnel, budgets, time – be spent in surveillance? Below are ten suggested criteria for deciding which diseases should be surveilled.

1. *Common*. Examples: varicella, streptococcal diseases. In the modern era, commonality is becoming a less important reason for surveillance.
2. *Important*. Examples: anthrax, dengue, leprosy, plague.
3. *Serious (fatal or causing severe disease)*. Examples: rabies, legionellosis.
4. *Detectable (by routine means)*. Examples: acute bacterial conjunctivitis, encephalitis, hepatitis.
5. *Intervenable (intervention possible in identified 'at risk' population)*. Examples: tuberculosis, measles.
6. *Controllable*. Examples: poliomyelitis, measles (eradicable); rubella (preventable); influenza, tuberculosis (amenable to public health control efforts).
7. *Researchable (subjects of interest for applied and public health research)*. Examples: influenza, dengue, legionellosis.
8. *Occuring in important sentinel or amplifying populations*. Examples: HIV in injecting drug users and commercial sex workers.
9. *Public interest*. Examples: Lyme disease, rabies.
10. *Of unknown cause*. Examples: Kawasaki disease, Reye syndrome.

Conclusion: the surveillance wheel

Surveillance is a core activity of public health. Surveillance data are mostly 'numerator data', collected passively by governments or large organisations, or actively by individuals. This activity allows us to understand, describe, and predict disease occurrence, anticipate and prevent morbidity and mortality, and optimise health expenditure decisions.

Good surveillance provides us with a community health risk appraisal, analogous to the value of personal health risk appraisals, as they are commonly used in the practice of preventive medicine with individual patients. Surveillance is the beginning of a circle that rotates from individual occurrences (e.g. diseases) to public health action.

The surveillance-response circle turns continually, like the wheels of a public health engine, in a cycle of surveillance, to data collection, to analysis, to decision, to action (response), to evaluation (CDC, 1988) and to new surveillance.

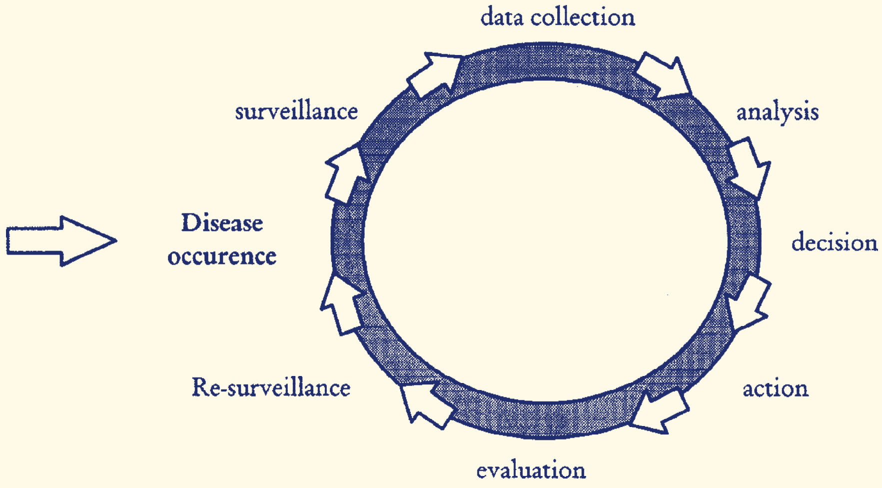

Figure 1. The Surveillance Circle or Wheel

Like the wheels of a public health engine, it turns continually in a cycle that begins with surveillance and leads to data collection, analysis, decision, public health action, and to evaluation of the results of action, which constitutes 're-surveillance', bringing the surveillance wheel full-circle.

To improve surveillance, it helps to think backwards, starting with the response, or with the possible response options, working back to the decisions that would lead to the response, back further to the analyses that would lead to the decision, and back even further to the data needed to perform the analyses. These, and only these, are the data to be collected.

As ontogeny is said to recapitulate phylogeny, so does the practice of public health surveillance recapitulate the essence and evolution of public health.

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