General principles of surveillance

Overview

Surveillance is the backbone of any disease control programme, even if the disease is not of infectious origin. This chapter provides the theoretical background for setting up a surveillance system. It covers the purposes and elements of surveillance, and its scope.

Learning objectives

After studying this chapter you will be better able to:

• explain the theoretical basis for setting up a surveillance system
• describe the purposes of a surveillance system
• define the different types of surveillance
• explain the broad scope of what can be put under surveillance

Key terms

Methicillin resistant staphylococcus aureus (MRSA) Another increasing and important public health problem, not only in hospitals but also in the community.

Prions Proteins which can enter cells and convert intracellular proteins into replica prions, causing infection. Human-to-human transmission occurs through blood transfusion, growth hormone injections, tissue transplants, food.

Reye syndrome Rare serious condition affecting infants and young children, causing brain and liver disease; associated with use of aspirin.

vCJD (Variant Creutzfeldt Jakob disease) A fatal brain disease caused by prions, spread from cows with a brain infection.

Definition of surveillance

Two dictionary definitions of surveillance follow:

• Chambers Dictionary: vigilant supervision; spy-like watching; superintendence.
• Oxford English Dictionary: supervision; watch or guard; especially over a suspected person.
Feedback

Here is a definition from John Last (1995): ‘Ongoing scrutiny, generally using methods distinguished by their practicability, uniformity and frequently their rapidity, rather than by complete accuracy. Its main purpose is to detect changes in trend or distribution in order to initiate investigative or control measures’. Your definition should have contained elements of the following, most but not all of them taken from the Last definition:

- ongoing collection of data
- practicality
- uniformity
- rapidity
- usefulness
- timely information for action

There are concepts important to surveillance in this definition. ‘Ongoing’ distinguishes surveillance from a survey, which is more finite. Practicality, uniformity and rapidity are self-explanatory. Definitions of what to report are helpful in ensuring uniformity, but this term also includes regularity. The emphasis on rapidity over accuracy is another important feature of infectious disease surveillance, but this does not mean that striving for accuracy is unimportant.

The Last definition does not emphasize sufficiently timely feedback for action. This is crucial for useful surveillance, especially of infectious diseases. In emergency situations in particular, such as with new infections or disasters such as the 2004 tsunami in South-East Asia, systematic collection of data is worthless without a timely response.

There are other definitions of surveillance which you may prefer. It doesn’t matter provided it covers the important elements above.

Activity 1.1

Can you make up a definition of surveillance of disease?

Activity 1.2

In what way does a survey differ from surveillance? How does surveillance differ from monitoring?
Feedback

Surveillance can also be distinguished from a survey because it usually makes use of already available data. The reports (e.g. a laboratory diagnosis) are generally obtained for clinical or other reasons, not just for surveillance. Thus surveillance is efficient because there is nothing extra to pay for in getting the information, only for having to send it to the surveillance centre. In a survey someone has to take steps to obtain information about a subject primarily for the objectives of the study, by using a questionnaire.

The term ‘monitoring’ should apply when an intervention has been put into place, and the result of the intervention has to be measured. Thus the effect of mass vaccination on a disease is monitored through surveillance of disease and surveillance of vaccine. Similarly the effects of hand-washing on nosocomial infection rates can be monitored in a hospital or ward.

Purposes of surveillance

Activity 1.3

Spend a few minutes thinking about the objectives of conducting surveillance. Write down as many points as you can.

Feedback

You should have written down at least some of the points included in Table 1.1. For the efficient running of any public health programme, surveillance is essential – indeed it has been called the backbone of public health. The basic purpose of surveillance is to

Table 1.1 Purposes of surveillance

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<th>Impact of disease</th>
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<td>• extent and limits</td>
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<th>Detection of changes</th>
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<td>• early warning</td>
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<td>• outbreak detection</td>
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<th>Monitoring effectiveness of preventive and control measures</th>
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<th>Highlighting priorities</th>
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Source: Noah (2002)
establish background information about a disease — or other factor, see below — in a population. This means not only incidence, but also the age, sex, geographical and seasonal distributions — i.e. time, place and person. Without this, it would be impossible to detect changes meaningfully and take action. Generally some public health action should be available for each disease under surveillance, although sometimes conducting surveillance on a new, emerging or severe infection may be necessary.

‘Measure of incidence’ may be a safer term to use than ‘incidence’ because surveillance rarely measures incidence — active or enhanced surveillance and a known and stable base population are usually necessary for this to be possible (see below). Nevertheless if reporting is consistent, changes in numbers reported may be indicative of changes in incidence. However, care must always be taken in interpreting changes in reporting numbers as changes in incidence.

The factors likely to affect changes in the numbers of cases reported in a laboratory surveillance system are:

• true change in incidence, including seasonal patterns;
• a new laboratory diagnostic method making the diagnosis easier or less expensive;
• increasing interest in the disease;
• someone making special efforts to increase numbers diagnosed (e.g. with an interest in the condition or writing a thesis);
• change in personnel (whether less or more motivated);
• economic effects, like a laboratory no longer being able to afford some tests;
• other spurious reasons, such as a laboratory or reporting centre failing to report.

In making the basic analyses by time, place and person, perhaps the most important purpose can be fulfilled — to detect change. Change may be natural or induced. Natural variations can be seasonal or secular. They can be useful for early warning or forecasting, or may signify some important change in the susceptibility of the population to that disease. Changes can be induced by some ‘accident’, such as an outbreak or a new disease, or purposeful, as with a vaccination or other public health intervention.

Subtle changes may occur without it being apparent in the numbers reported, just as undercurrents may not disturb the surface of water.

Activity 1.4

1. Figure 1.1 gives the numbers of notifications of infective hepatitis. What do you observe?
2. Look at Figure 1.2 and comment on what you observe.
Figure 1.1 Rates of notification of infective jaundice in district A, 1975–8
Source: Adapted from Limentani et al. (1979)

Figure 1.2 Rates of notification of infective jaundice in district A, 1976–8, by age and sex
Source: Limentani et al. (1979)
1 There seems to have been an increase in notified rates in 1976 and low rates in 1975. In 1976 and 1978 there were summer peaks, in 1977 a winter peak. Was there possibly an outbreak in 1976? This seems to be the only feature of interest in this figure.

2 The age and sex distributions in the three years of higher incidence show quite clearly that an outbreak of jaundice affected young men aged 15–29 in 1978. Nearly all of them had in fact contracted hepatitis B from one tattooist. Figure 1.3 shows how the tattooed cases had been hidden by other cases and causes of jaundice. Because infective jaundice was being notified rather than a specific form of hepatitis, comparing four years of notifications would not have uncovered the outbreak – in Figure 1.1, 1978 was unremarkable. However, the age and sex analyses instantly revealed that something unusual was happening.

If surveillance data cover a large area, changes may occur within a district or smaller area, and may not be detectable unless data are analysed by place. The invaluable part played by surveillance in the early detection of outbreaks will be discussed further in Chapter 5.

Surveillance can also detect groups of people who may be especially vulnerable to a disease. Fairly sophisticated surveillance systems may be needed for this, but vulnerable age groups or geographical areas can sometimes be detected with even basic systems. It is not possible to monitor successfully the success or otherwise of any public health interventions without surveillance.
Activity 1.5
Can you think of some examples of public health interventions for which surveillance is essential? For each example list what you would need to put under surveillance.

Feedback
Some public health interventions for which surveillance is essential include:

- the effects of mass vaccination on the infection
- the effects of the introduction of sanitation and clean water supplies on diarrhoeal disease
- controlling an epidemic of salmonella by withdrawing a contaminated food
- monitoring the effect on legionnaires’ disease of a law requiring regular maintenance of wet cooling towers

For a mass vaccination programme, surveillance of the numbers of cases of disease and uptake of vaccine is essential. More sophisticated surveillance systems should include changes in the age distribution of the disease, side-effects of the vaccine, immunity levels of the population and enhanced surveillance of cases (see below) as they become fewer. These are discussed in the chapters on vaccines.

For sanitation, numbers of cases of diarrhoea in the areas in which sanitation has been introduced could be compared with areas without sanitation or the period before sanitation. In more advanced systems, laboratory reports should be included.

If an outbreak of salmonella has been caused by a widely-distributed foodstuff, the numbers of cases after the cause has been withdrawn or otherwise treated should be monitored. The number of outbreaks can also be part of surveillance. The mass immunization in the UK of chickens against salmonella infection led to a dramatic fall in the numbers of *Salmonella enteritidis* PT4 infection. This had a ‘double effect’ in reducing not only food poisoning from chickens but also from hens’ eggs.

The reported incidence of legionnaires’ disease and the source of cases can be compared before and after the law was introduced.

Sentinel surveillance
Sentinel surveillance is essentially a type of ‘sample surveillance’. Reporting sources are situated at various sites covering an area (which may be very large, such as a country), and may provide complete reporting within the population covered by each reporting source.
Activity 1.6

Can you think of some situations in which sentinel surveillance would be the best option? Why or when would you use sentinel surveillance rather than any other type of surveillance?

Feedback

General practice (primary health care) systems are the ideal base for using sentinel surveillance. If the GPs know the age and sex distribution of their patients, incidence and prevalence data can be calculated. However, because the sentinel practices are by definition widely distributed, the diseases under surveillance have to be fairly common, with little if any geographical variation, so that if there are large areas under- or not represented, it will not matter.

Common illnesses such as chickenpox, herpes zoster or gastroenteritis are ideal for sentinel surveillance. Indeed one would prefer to use sentinel surveillance rather than notification for such conditions: first because it would be wasteful to use a large unwieldy system for common diseases, and second because the compliance and accuracy associated with a sentinel surveillance system is usually considerably better than with a countrywide system. In a sentinel system the reporting personnel tend to be more motivated and likely to make more accurate diagnoses. Each source of information is usually a volunteer, or chosen at random but with agreement. Laboratories and hospitals can also be used as part of a sentinel surveillance system, either as part of a GP-based one or on their own. The same principles apply – use for common diseases with little geographical variation.

Active surveillance and enhanced surveillance

Most surveillance is passive, in the sense of reporting being automatic and there being no real control over the regularity and consistency of the reporting sources. Notification systems generally are an example of this. The surveillance centre is, in effect, accepting some incompleteness in the data. Negative reporting is not required in passive surveillance.

Sometimes, however, more complete reporting is required. The global eradication of smallpox is the best-known example of this: ‘each local health unit was “coerced, persuaded, and cajoled” to report cases of smallpox each week, intensive further case finding was undertaken when a case was notified, and sources of information other than medical – teachers, schoolchildren, civil and so on – were used’ (Henderson 1976). Completeness was crucial to smallpox eradication.

In infections for which the goal is eradication or elimination, the closer one gets to the target, the greater the demand for completeness and accuracy of reporting. When measles was common in England and Wales, notifications were adequate. Even at around 500,000 cases a year pre-immunization, they were probably
incomplete but accurate enough for the purpose, *i.e.* the system could cope with a few misdiagnoses. Even when mass immunization was first introduced, in 1968, and the number notified began to fall (see also Chapter 3), notifications were sufficient. When, however, the immunization campaign was stepped up in the late 1980s to achieve elimination, and cases began to be reported in hundreds rather than thousands, completeness and accuracy achieved greater importance and the diagnosis in each case had to be confirmed. Only in this way could the success of the elimination targets be assessed.

Examples of where completeness of reporting is important include:

- less common but important conditions, especially those for which a vaccine is available: more active surveillance required, *e.g.* meningococcal infections;
- conditions for which public health measures such as quarantine/isolation, chemoprophylaxis, vaccination or immunoglobulin are necessary: completeness/accuracy important, *e.g.* meningococcal infection (chemoprophylaxis, vaccination) and viral haemorrhagic fever (quarantine/isolation) are examples;
- highly contagious infections for which contact tracing is required: completeness essential, *e.g.* diphtheria, smallpox, SARS;
- very rare diseases which are not necessarily preventable, but for which more information is required: active surveillance indicated, *e.g.* see BPSU below;
- serious infections such as botulism, rabies; some new diseases, such as variant CJD: completeness and accuracy essential; although some of these infections, which include rabies and vCJD, are rarely transmissible from human to human, this usually occurs under somewhat artificial conditions (blood transfusion/tissue transplantation), and the risk of human infection is not the primary reason for placing them under surveillance.

Active surveillance requires negative reporting of reporting sources – if a reporting source has no cases they must send in a negative return. Sometimes telephone follow-up is done by the surveillance centre. An example is the surveillance run by the British Paediatric Surveillance Unit (BPSU) in London. They initially started surveillance for Reye syndrome, a rare but serious condition affecting children. Many other conditions have now undergone surveillance through the BPSU, interestingly each for only a limited period. Several other similar systems, modelled on the BPSU, now exist in other countries, and an international network of Paediatric Surveillance Units was formed in 1998 (Lynn *et al.* 1999).

‘Enhanced surveillance’ is a term coined in England and Wales for a particular type of surveillance in which certain regions or areas are selected to perform active surveillance. It is suitable for infections which are fairly common, such as meningococcal infection. Before the vaccine against group C meningococci was introduced on a mass scale, it became important to assess the real incidence of the infection. Thus all laboratories, hospitals and family doctors were alerted in the areas concerned to report cases, ensuring completeness as far as possible. Steps were taken to eliminate duplicate reporting.
Scope of surveillance

Disease should be considered as a dynamic process which includes the ecology of the pathogen, host, reservoir, vectors and the environment. This is an important concept at all levels of disease control, from the clinical doctor treating the patient at the bedside to the public health practitioner attempting to prevent disease at a population level. Similarly we now broaden the concept of surveillance from the surveillance of disease to surveillance of factors that can affect disease. Examples of surveillance at each level are shown in Tables 1.2, 1.3 and 1.4.

Surveillance of morbidity is the surveillance of disease, but can be at various levels (e.g. general practice or hospital). Most notification systems depend on GPs but there are also some specific GP-based systems based on non-notifiable but important diseases. Hospital-based systems clearly measure disease at a more serious level.

**Table 1.2 Surveillance of disease**

- Disease
  - Mortality
  - Morbidity
  - Outbreaks: disease and environment
  - Laboratory
- Drug utilization
  - Therapeutic
  - Diagnostic
  - Prophylactic
- Vaccine
  - Utilization and efficacy
  - Side-effects

Source: Noah (2002)

**Table 1.3 Factors relating to determinants of disease**

- Biological functions
  - Growth
  - Development
  - Nutritional status
- Biological changes in agents
  - Influenza
  - Antibiotic resistance
- Reservoirs of infection
  - rabies
  - malaria
  - brucellosis
- Vectors of infection
- Environmental and occupational
  - Pollution
  - Natural phenomena
- Social disease determinants/lifestyle

Source: Noah (2002)
Death certification is the usual source of data on mortality, but reporting of deaths as part of a surveillance system can be particularly useful because case fatality rates may be calculable, as when deaths are routinely reported through a laboratory surveillance system.

Activity 1.7

If several different sources of information are available for a given infection, is it wasteful to use more than one of them?

Feedback

Not necessarily. Because a disease has many different facets, different types of information can be helpful. Food poisoning is notifiable, and most of the information comes from family doctors. However, laboratory reports provide vitally important detail on whether the cause is salmonella, norovirus, staphylococcal etc. Notifications of meningococcal disease or bacterial meningitis provide early warning of an infection, but hospital and laboratory data give detail on the type of infection and are more likely to be complete.

It should be noted that laboratory surveillance offers primarily a qualitative aspect to surveillance of disease. By this is meant that, with the biases inherent in laboratory reporting, incidence rates for a particular infection cannot often be calculated. Nevertheless, laboratories provide essential detail about clinical diagnoses for which the details provided may be insufficient – further examples include hepatitis or influenza.

Death certification gives yet another perspective on the severity of the disease. Surveillance of infection at different levels is discussed in more detail later in this chapter.

For economic or other reasons it may not always be feasible to report individual cases of infection. If so, setting up a system for reporting outbreaks or suspected outbreaks may be considered. These can then be investigated and controlled. Outbreak surveillance is valuable in its own right. It can produce information on the number and size of outbreaks, the importance of an organism in causing outbreaks.

Table 1.4 Factors relating to susceptibility to infection

- Antibody studies
- Skin testing
- HLA/blood groups
- Enzyme deficiencies
- Pharmacogenetic

Source: Noah (2002)
and on the type of outbreak – for example, types of catering (restaurants, caterers etc.) most likely to need training and education in food handling techniques. Outbreaks can be reported on suspicion by family doctors, public health professionals, the media and even members of the public, and then further investigated for confirmation and control.

Surveillance of drug utilization also has potential. For this to be useful, only drugs that are fairly specific for certain conditions, such as pentamidine which used to be the main treatment for Pneumocystis carinii pneumonia, can be monitored, and high-quality statistical information systems must be present to monitor their use. Surveillance of vaccine usage is discussed in more detail later. The use of some vaccines, such as influenza vaccines, to monitor their uptake is still fairly underdeveloped.

### Biological changes in agents

With the ability of micro-organisms to change and adapt, surveillance for detecting biological changes in agents is clearly of vital importance in the fight against disease. Such changes in micro-organisms occur frequently. Many of these appear to be ‘natural’ – for example, the subtypes and variants of influenza A virus (change); others, notably the development of antibiotic resistance, are in response to man’s efforts to treat infections (adapt). Examples include:

Influenza A virus changes periodically – major changes are called shifts and the ‘new’ virus is a subtype. Minor changes are drifts and the changed virus a variant.

Serotypes of meningococci show considerable variation from time to time. Whether these are ‘natural’ or in response to human susceptibility is not clear. Antibiotic resistance which has developed in some meningococci is certainly adaptation.

Strains of *Staphylococcus aureus* have developed resistance to methicillin (MRSA), making treatment of these infections much more difficult.

Enteric bacteria have likewise developed resistance to antibiotics, notably *Escherichia coli* to vancomycin, and *Salmonella typhi* to chloramphenicol.

Multidrug resistance to *Mycobacterium tuberculosis* has made its treatment, and both treatment and prophylaxis of malaria, much more complex.

### Reservoirs of infection

Humans can act as reservoirs of infection. Typhoid, malaria, measles, whooping cough, rubella, mumps, smallpox and hepatitis A (as well as hepatitis B and C) are examples of this, even though some of these organisms can also infect other primates.

Cows, sheep, goats and pigs are the main reservoirs for brucellosis in man, and many biting mammals (but not rodents) for rabies. Influenza affects many animals and birds, and the mixing of strains is thought to be the main source of new
subtypes affecting man. Other examples you may have thought of include psittacosis (birds and sheep), leptospirosis (pigs, dogs, rats, cattle, raccoons and others), Lyme disease (ticks, rodents and deer), lassa fever (multimammate rats), various tick-borne infections (both ticks and animals), plague (wild rodents mainly), Q fever (domestic and farm animals, birds and ticks) and salmonellas excluding typhoid (animals, reptiles and birds).

Examples of infections for which the environment is the main reservoir include Legionellas, Clostridium tetani and C. botulinum, Listeria (probably some animals as well) and meliodosis Most of these dwell in soil and water. Some, such as tetanus, come from the intestines of horses and other animals, and are excreted into the soil.

Surveillance of animal and bird reservoirs is useful for assessing risks to humans. For eradication, surveillance of infection in animals is probably essential (e.g. detection and treatment, usually by culling, of cattle in brucellosis). Tuberculosis eradication schemes (M.bovis) rely on efficient surveillance. Surveillance of influenza A subtypes in birds and animals in many countries of the Far East is now well developed.

Other types of surveillance (see Table 1.3) may have an indirect bearing on infection (e.g. lifestyle and social trends on the incidence and characteristics of STIs, and pollution on respiratory infection). For some useful information on surveillance of non-communicable disease risk factors see ‘useful websites’ below.

**Susceptibility to infection**

Factors relating to susceptibility to infection were listed in Table 1.4.

Most of these are potential rather than existing examples of surveillance of factors related to susceptibility, and are included here to show some future possibilities. As long ago as 1971 Raska argued for the use of serum banks and immunological surveys in surveillance. Antibody surveys – serosurveillance – are now well developed, and can assess susceptibility of populations to infection and the need for vaccination (Morgan-Capner et al. 1988). In England and Wales, small samples of the population are regularly tested for antibodies to the latest circulating influenza variants and to new variants. In this way the probable response to an existing influenza vaccine – or the need for a new strain to incorporate into the vaccine – can be evaluated. Susceptibility to infection can also be measured by skin testing, as used with diphtheria (Schick test) and tuberculosis (tuberculin), though these are rarely if ever used for surveillance.

**Multidisciplinary surveillance**

From the above, it should be clear how wide is the scope for surveillance and how, often, many facets of one disease need to be placed under surveillance. Coordinating with veterinarians is essential for diseases such as salmonella, brucellosis, leptospirosis, tuberculosis, influenza and many others. With the arbovirus diseases,
malaria and many other tropical infections, the surveillance of human disease in isolation is usually inadequate – animals, insects and the environment are vital loops in the chain of transmission. Microbiologists working with animals, birds, and insects as well as those with information on the environment (rivers and lakes in particular) may be vital partners in the team.

Summary

Surveillance is fundamental to public health. In this chapter you have learnt about different types of surveillance and the broad scope of the type of information – not relating just to disease, but also to the determinants of disease – that can be placed under surveillance.

References


Useful websites

Health Protection Agency (HPA). The HPA in England and Wales plays a central role in the surveillance and control of infectious diseases: http://www.hpa.org.uk/.

The HPA Centre for Infections websites are particularly useful for up-to-date surveillance reports: http://www.hpa.org.uk/infections/default.htm and http://www.hpa.org.uk/cifi/about/epidem_surveil.htm.

The weekly *Communicable Disease Report* is freely available at http://www.hpa.org.uk/cdr/index.html

Eurosurveillance is freely available weekly and monthly: http://www.eurosurveillance.org/index-02.asp.

British Paediatric Surveillance Unit (BPSU), London: http://bpsu.inopsu.com/.

For epidemiological surveillance: http://www.who.int/topics/epidemiologic_surveillance/en/.
For surveillance of risk factors: http://www.who.int/mediacentre/factsheets/fs273/en/

CDC website: http://www.cdc.gov/doc.do/id/0900f3ec8022729e.