Surveillance for Early Detection and Monitoring of Infectious Disease Outbreaks Associated with Bioterrorism

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Abstract

The appearance of "new" infectious diseases, the reemergence of "old" infectious diseases, and the deliberate introduction of infectious diseases through bioterrorism has highlighted the need for improved and innovative infectious disease surveillance systems. Traditional current surveillance systems are generally based on the recognition of a clear increase in diagnosed cases before an outbreak can be identified. For early detection of bioterrorist-initiated outbreaks, the sensitivity and timeliness of the systems need to be improved. Systems based on syndromic surveillance are being developed using technologies such as electronic reporting and the internet. The reporting sources include community physicians, public health laboratories, emergency departments, intensive care units, district health offices, and hospital admission and discharge systems. The acid test of any system will be the ability to provide analyses and interpretations of the data that will serve the goals of the system. Such analytical methods are still in the early stages of development.

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Surveillance systems for infectious diseases are used for early detection of outbreaks, analyzing trends and generating hypotheses [1–3]. It is generally agreed that current surveillance systems need to be improved in order to cope with emerging and reemerging infectious diseases. The recent intentional spread of anthrax in the United States and the increased potential for bioterrorist attacks has introduced an additional importance for surveillance systems. Both diseases caused by bioterrorism and emerging infectious diseases would manifest as unusual outbreaks of disease [4]. The issue is whether traditional surveillance systems are suitable for early recognition of such outbreaks and ensuring that the information is made available promptly to the relevant public health decision-makers. In this paper, traditional surveillance systems are compared with the new systems currently being developed.

When comparing surveillance systems, a number of basic topics need to be addressed [5]. The goals of the system should be analyzed, including specifications of the kind of information that is expected. All those responsible for the surveillance should be identified and their roles delineated. Both the protocols for the surveillance methodology and how it will be evaluated must be examined. Finally, the system should include procedures to be followed in the event that an incident is suspected, including how and to whom it should be reported.

The success of a surveillance system depends on a number of factors including simplicity, flexibility, data quality, acceptability, sensitivity, predictive value positive, representativeness, timeliness and stability [5]. Sensitivity and predictive value are clearly important to measure the usefulness of the system [6]. Simplicity and acceptability are arguably the most critical factors that influence the functioning of a surveillance system. The U.S. Centers for Disease Control and Prevention [5] has proposed that the simplicity of the system be measured by the amount and type of data necessary, amount and type of related data necessary, number of organizations involved, and level of integration with other systems. Technical factors to be considered include method of collecting data, duration of follow-up, method of managing the data, methods for analyzing and disseminating the data, staff training, and time spent on maintaining the system.

The CDC [5] suggests a number of factors that can affect acceptability. Perhaps most important are public health importance, feedback to reporting sources, responsiveness of the system, amount of time, and ease and cost of data reporting. Other factors include legal assurance of privacy and confidentiality, ability of the system to protect privacy, legal requirements for data collection, and cooperation of health personnel. In various studies of the compliance of physicians reporting notifiable conditions, deficiencies in the above-mentioned factors appear repeatedly as predictors of poor compliance [7–10].

Traditional surveillance systems

The CDC defines public health surveillance as "the ongoing systematic collection, analysis and interpretation of outcome-specific data for use in the planning, implementation and evaluation of public health practice" [2,5]. The prime goal of traditional infectious disease surveillance is to identify changes in incidence either in the form of an acute outbreak or in a change in long-term trends. Traditional surveillance systems are based on the compulsory reporting of specific, diagnosed diseases to a central health authority. In some instances, non-specific syndromes are monitored as markers for specific diseases. Examples include surveillance for influenza-like illness as an indicator of influenza activity [11,12], or surveillance for acute flaccid paralysis as an indicator of possible cases of paralytic poliomyelitis [13]. The potential benefits of early detection and monitoring for a disease such as influenza include immunization, treatment, allocation of health services, and introduction of measures to limit spread of the

CDC = Centers for Disease Control and Prevention

disease. For other diseases, factors such as quarantine, isolation and preventive medications are important.

In order to identify a change in incidence, a certain critical number of events is required. This number of events will depend on the rarity of the disease. For example, a large number of cases of a common disease such as hepatitis A virus infection would need to be observed in order to conclude that a change in incidence has occurred. On the other hand, in an area long free of malaria, even a single locally acquired case would be enough to signal a change. Both these situations require that the disease is diagnosed. Once the outbreak has been identified, its progression can be monitored by time, geographic region and selected demographic characteristics of the cases.

Deficiencies of traditional surveillance systems

In the USA, an evaluation of the West Nile virus epidemic yielded useful information on current deficiencies in the traditional surveillance systems [14]. There were communication gaps between primary care providers and public health departments, between the animal and human health authorities, and between public health specialists and intelligence analysts. The report provided a number of policy recommendations, including expanding training of primary healthcare providers, establishment of simple reporting mechanisms at city and state level (hot lines), and increasing the number of competent laboratories. In addition, they pointed to the need to provide basic information on the bioterrorism threat, expand electronic reporting, attract people to the public health field, and assist hospitals to cope with bioterrorist threats.

Surveillance for bioterrorist-initiated outbreaks

The dominant characteristic of a classical bioterrorist-initiated outbreak is the exposure of a large number of people during a short period. The recent inhalation anthrax outbreak in the USA, where exposure occurred through the mail, is an example of multiple common source outbreaks. An important objective in bioterrorism surveillance is the very early detection of the first symptomatic cases. Since the pathogens most likely to be used in a bioterrorist event produce diseases characterized in their early stages by non-specific symptoms and signs, syndrome surveillance is used for early detection of the outbreak. The assumption that any well-functioning surveillance system designed to detect outbreaks of naturally occurring diagnosed diseases can be adapted to syndrome surveillance for bioterrorist incidents may not necessarily be true. For example, a surveillance system for a disease such as influenza (diagnosed either clinically or virologically) may not be suitable for the early detection of deliberately caused outbreaks using organisms such as anthrax, plague or smallpox. The traditional systems are generally relatively insensitive to detecting the initial cases, where the symptoms and signs are non-specific.

At present, early identification of deliberately caused diseases will depend largely on the ability of primary care and emergency department physicians to identify and immediately report typical cases. This in itself is not a trivial issue. The diagnosis of rare diseases, even with clear clinical manifestations, will not necessarily be obvious to the physician whose only knowledge of the disease comes from lectures and textbooks. At this level, the main action to be taken is to educate and regularly update physicians on the clinical manifestations of diseases that may result from bioterror or biocrime.

The reporting procedures also need to be adapted to syndrome surveillance. When a highly infectious or unusual disease is diagnosed or strongly suspected, the procedure to be followed is usually clear. In most cases, the physician should report by telephone to the public health authorities and this should initiate an epidemiologic investigation. If bioterrorism is suspected, the relevant authorities must be notified. However, when syndrome surveillance is used, the problem arises of an abundance of false reports. The challenge is to tailor automatic surveillance systems to function efficiently in the long term, without overburdening the public health services.

There are a number of possible sources of information for syndrome surveillance systems. Most prominent are primary care physician visits (sentinels), emergency department admissions, infectious disease specialists, deaths suspected from infectious diseases, and reports of outbreaks to the district health offices. Other markers of a change in morbidity incidence include hospital bed occupancy, intensive care unit use, specimens submitted to laboratories (blood, cerebrospinal fluid, stools, sputum), work and school absenteeism, sales of pharmaceuticals, meteorologic factors, and animal data.

The benefits of electronic reporting are primarily the timeliness of reports and less reliance on the individual physicians to complete forms. Feedback to the reporting physicians is essential in order to maintain their motivation to report accurately and promptly. Syndrome surveillance will require implementation of statistical procedures and mathematical modeling as tools to achieve the main goal of early detection of unusual infectious disease outbreaks. Detection of clusters is one of the more important features of any surveillance system. The use of geographic information systems can be a valuable tool for detecting clusters. International data sharing will be crucial to detect the onset of pandemics and will increase the professional capacity of individual countries.

Early detection capabilities have to be coupled with rapid identification of the pathogen that elicited the outbreak in order to produce a prompt and effective response. New technologies have been developed to hasten the pathogen recognition process. One of those innovative technologies is the "Biochip" technology [15]. Biochip is a miniature device based on DNA probes captured on a chip, which enables quick and simultaneous identification of several pathogens on the spot. Timely reporting of laboratory results is essential for early detection, and electronic reporting is a key element in improving current systems. This was one of the purposes of establishing the Public Health Laboratory Information System in the USA [16–18].

Examples of new surveillance systems

As part of the measures taken by the U.S. government to cope with the threat of bioterrorism, funds have been allocated to various public health agencies to build innovative surveillance systems. The

goal is to develop capabilities for early detection and monitoring of infectious disease outbreaks [19]. A number of such systems have been developed and are based on information about symptoms and signs such as fever, headache, diarrhea, vomiting, coughs or rash. Some also collect data on sudden deaths. Examples of recently developed surveillance systems are described. The more basic methods tend to be extensions of the traditional systems. There is an increasing trend to take advantage of the flexibility of the internet.

Non-internet-based surveillance systems

Since 1999, the New York City Department of Health has been actively monitoring hotline calls (911) on a daily basis to identify temporal or geographic increases in respiratory illnesses that might represent any infectious disease outbreak, including seasonal influenza as well as a potential bioterrorist event [20]. The Health Department also developed three independent and complementary systems to monitor community-based gastrointestinal outbreaks. These include sales of anti-diarrheal medications, submission of stool samples for laboratory tests, and incidence of gastroenteritis in nursing home populations. Data are analyzed for unexpected variation. The New York City Health Department is also actively monitoring syndromes of people admitted to emergency departments of several hospitals in the New York area. Their local version of SatScan software, originally developed by the National Cancer Institute, is used to identify possible clusters, which can signal a common source of infection (personal communication).

The U.S. Department of Defense's Global Emerging Infectious Surveillance and Response System (DoD-GEIS) developed the ESSENCE (Electronic Surveillance System for the Early Notification of Community-based Epidemics) to rapidly identify the occurrence of non-specific syndromes in patients presenting at military healthcare facilities in the Washington DC area [21,22]. ESSENCE uses daily ambulatory data already being collected at hospitals and clinics and transmitted to a central database. Epidemiologists at DoD-GEIS can use these to follow syndromes being reported in this area.

Daily analyses are compared with historical trends and patterns that suggest an infectious disease outbreak can be detected. If there is a significant change in the number of reports compared with that expected, military and civilian public health officials are notified. The frequency of outpatient visits for the different syndrome categories are also mapped using geographic information system software. Plans are under way to monitor other data such as over-the-counter pharmaceutic sales and school absenteeism.

Internet-based surveillance systems

The Rapid Syndrome Validation Project system is a collaboration of several institutions including Sandia National Laboratories, Los Alamos National Laboratory, the University of New Mexico Department of Emergency Medicine, and the New Mexico Department of Health Office of Epidemiology [23,24]. It is a touch-screen based system that runs in a web browser and enables healthcare providers in emergency department settings to rapidly enter clinical and demographic data on patients with one of a variety of infectious disease syndromes. Six syndromes have thus far been evaluated: flu-like illness, fever with skin findings, fever and altered mental status, acute bloody diarrhea, hepatitis, and adult respiratory distress syndrome.

The system provides a geographic plot of syndrome reporting, a temporal plot of similar syndromes over the past several weeks, and a summary of viral laboratory cultures reported in the community. In addition, there are several alert screens that display updated information on disease outbreaks, other relevant epidemiologic information, and links to web-based information sources. The New Mexico Department of Health has access to all of the above data for each of the six syndromes reported by physicians.

LEADERS (Lightweight Epidemiology Advanced Detection and Emergency Response System) is a product of a consortium including the U.S. Air Force, Sandia National Laboratories, ORACLE corporation, ScenPro, EYT, and Idaho Technology [25]. The system is being developed to assist military, medical and emergency response personnel in dealing with outbreaks of natural disease or a biologic warfare event. One of its strengths is that it is an Internet-based system enabling large-scale data collection and can be tailored to fit the user's demands. All the needed applications to run the system are accessible through a central Application Service Provider. LEADERS comprises five modules. One example, the MedSurv module, is an early warning system for infectious disease outbreaks based on syndrome surveillance. It enables public health departments to detect changes in incidence and quickly assess potential health risks. Its web technology is particularly useful for mining syndrome data. The Israel Center for Disease Control is collaborating with Sandia National Laboratories in a project to validate the system.

Rough indications of unusual events on a global scale can be deduced from messages posted by ProMed-mail. ProMed-Mail is an Internet-based reporting system dedicated to rapid and global dissemination of information about outbreaks of infectious diseases that affect human health.

Conclusions

During the last few years there has been a surge in the development of surveillance systems for early detection and monitoring of bioterrorist-initiated infectious disease outbreaks. The premises that should guide the design of such systems could usefully be summarized in the following points:

- It is highly unlikely that the individual physician will be able to recognize the initial cases of bioterrorist-initiated disease due to the non-specific symptomatology and the paucity of cases per individual physician.
- Traditional surveillance systems that are based on single sources will be too non-specific for early identification of intentionally caused disease, and methods will have to be developed to integrate data from multiple sources into a single surveillance system.
- Since surveillance systems for bioterrorist outbreaks should be oriented towards detection of unusual diseases, spread in unusual ways, it seems logical that specialists on bioterrorism

surveillance should be involved in both developing and maintaining such systems.

- Innovative analytic procedures will be needed for both early detection and monitoring of the spread of the outbreak and identifing the source.

Finally, regardless of which system is used, healthcare professionals at many levels will need to play much far active roles in disease surveillance than in the past.

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