BIOSECURITY AND BIOTERRORISM: BIODEFENSE STRATEGY, PRACTICE, AND SCIENCE
Volume 1, Number 4, 2003

Syndromic Surveillance: The Case for Skillful Investment

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PUBLIC HEALTH SURVEILLANCE is the ongoing, systematic collection, analysis, interpretation, and dissemination of data regarding a health-related event that enables public health authorities to reduce morbidity and mortality.[1] Surveillance serves many public health functions—for example, estimating the burden of a disease or injury, portraying the natural history of a condition, determining the distribution and spread of illness, generating hypotheses and stimulating research, supporting disease control interventions, evaluating prevention and control measures, and facilitating planning.[2]

One important public health function of surveillance that is particularly relevant to biodefense is outbreak detection—that is, the ability to detect an abnormal rise in the frequency of a disease. Infectious disease outbreaks typically have been recognized either through accumulation in public health departments of case reports of suspected or diagnosed cases of a reportable disease, or by alert health care professionals, laboratorians, or the public bringing cases and clusters of diseases to the attention of public health authorities. Syndromic surveillance (defined below) is an approach to public health surveillance that may extend current capabilities to detect outbreaks early in their course.

The concept of syndromic surveillance has not been clarified precisely, however, and expectations of what such surveillance can accomplish vary widely. Evaluation of the effectiveness of syndromic surveillance as one component of a comprehensive strategy for outbreak detection is urgently needed so policy makers can determine if, when, and how this technique should be applied.

WHAT IS SYNDROMIC SURVEILLANCE?

As a form of public health surveillance, syndromic surveillance is the ongoing, systematic collection, analysis, interpretation, and application of real-time (or near-real-time) indicators for diseases and outbreaks that allow for their detection before public health authorities would otherwise note them. Syndromic surveillance is distinguished from other methods of surveillance by the data types that are monitored as potential indicators of a disease or outbreak. For the purpose of detecting bioterrorism, indicators are nonspecific expressions of the target diseases that occur before a diagnosis would routinely be made; these might include absenteeism from work or school, purchases of health products, phone calls to or Internet use of a health-care information site, laboratory test requests, or visits to a health-care facility with, for example, symptoms suggesting upper respiratory infection. Not all cases of the target disease will manifest the monitored expressions of disease, and many other conditions will also express these characteristics at an early stage, thereby limiting the sensitivity and specificity of these systems for detection of diseases and outbreaks.

Syndromic surveillance is not a new concept; surveillance of acute flaccid paralysis, a highly specific syndrome, has been used for detection of polio cases and for outbreak control over the past decade,[3] and influenza-like illness has been tracked to clarify the timing and characteristics of annual influenza outbreaks.[4]

However, syndromic surveillance for a bioterrorist-related outbreak is a new concept that emphasizes timeliness and applies automated analysis and visualization tools to screen nonspecific indicator data in electronic form so as to detect unexpected patterns that warrant investigation. The advantage of syndromic surveillance is the lead-time it provides public health authorities to take more effective public health actions. What syndromic surveillance allows is not necessarily earlier diagnosis per se but the ability to mobilize public health investigation and response capabilities before disease and outbreak confirmation.

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WHY SYNDROMIC SURVEILLANCE?

Models of large-scale exposures to biological agents of terrorism suggest dramatic potential for saving lives and expense (e.g., through use of antibiotics and vaccination) in the early days following exposure—and the earlier the better.[5] Although the primary purpose of syndromic surveillance is outbreak detection, it is only one possible component of a comprehensive outbreak detection strategy. In the United States, the foundation of infectious disease surveillance is the National Notifiable Disease Surveillance System (NNDSS) (http://www.cdc.gov/epo/dphsi/nndsshis.htm). NNDSS lists diseases of public health interest and provides case definitions for their surveillance and a mechanism for sharing data across levels of government. It is supported by two-way communications between public health authorities and clinicians to increase awareness of disease patterns and risks and to support consultation and reporting events of public health interest.

NNDSS functions are supported by the Public Health Information Network (PHIN), which aligns data and vocabulary standards for public health with national health care information system standards (http://www.cdc.gov/phin/). These standards will ultimately enable real-time data flow within public health and across health-related information systems and support computer-assisted analysis, decision support, professional collaboration, and rapid communication. The emerging standards will facilitate the linkage of electronic collection and analysis to timely epidemiological investigation and support for managing the public health response to an outbreak or terrorist event. Electronic laboratory reporting—that is, the automated transfer of designated data from a laboratory database to a public health data repository by using a defined message structure[6,7]—illustrates how the PHIN model for managing real-time data flows can support more timely and complete reporting of notifiable conditions, which will enable earlier outbreak detection. Statistical tools for improved pattern recognition and aberration detection can support awareness of unusual patterns of disease and indicators earlier than traditional analytic techniques.[8]

Unfortunately, we are years away from widely available real-time electronic sharing of notifiable disease data between clinical medicine and public health. The current notifiable disease surveillance system is vulnerable to incomplete and delayed reporting of public health threats. Health care provider and laboratory outreach, education, and continuous, privileged access to public health professionals are needed to enhance reporting of unusual diseases and disease patterns consistent with outbreaks from agents of terrorism. Additionally, leveraging existing indicator data in real-time syndromic surveillance offers the potential for early outbreak detection while supporting the development and implementation of standards for electronic sharing of health data.

Increasing the timeliness of outbreak detection can be achieved in three ways: 1) through more timely and complete receipt, review, and follow-up of disease case reports (i.e., prompt reporting by physicians, health care facilities, and laboratories consistent with disease reporting laws); 2) by routine application of statistical methods and data modeling that draws the attention of public health investigators at an earlier stage of an outbreak (i.e., when fewer cases have occurred); and 3) through analysis of new types of data that can signify an outbreak before the clinical diagnosis and epidemiological linking of cases can be accomplished.[9] Syndromic surveillance is intended to incorporate aspects of all three approaches to early outbreak detection by leveraging real-time electronic health indicators available today, by applying automated pattern recognition tools to screen for possible outbreaks requiring public health investigation and confirmation, and by monitoring health indicators that occur early in the course of illness.

WHAT DO WE KNOW ABOUT SYNDROMIC SURVEILLANCE?

Our knowledge of the effectiveness of syndromic surveillance as a tool to detect disease outbreaks is currently limited. The growing literature that describes various syndromic surveillance systems suggests theoretical benefits and costs.[10–18] Validation studies to date have focused largely on the relationship between defined syndromes and subsequent clinical diagnoses[19–25] and on simulations of detection algorithms.[26–28] One retrospective analysis correlated emergency department syndromes with health department case reports and inferred an average lead-time of one day for emergency department syndromes before case reports were received by the health department.[29] Published evaluations of other attributes are rare.[30] Experience with outbreak detection has been conveyed primarily through meeting presentations, abstracts, and personal communications, with findings demonstrating retrospective correlation with outbreaks and prospective detection of outbreaks and clusters of gastrointestinal illness and influenza-like illness,[12,31–44] alarms during high-profile events without detecting outbreaks,[45–47] and known outbreaks being missed by syndromic surveillance systems.[48,49]

Retrospective correlation is the weakest of positive findings, demonstrating through hindsight that an outbreak was evident in the data. Prospective detection demonstrates that the system is able to detect outbreaks or smaller clusters of disease through continuous monitoring of surveillance data; however, these findings have not yet established an advantage over traditional outbreak detection methods. Neither outbreaks nor acts of terrorism were detected by syndromic surveillance during high-profile political and sporting events in the U.S. in spite of suggestive patterns in the data that were subsequently investigated and dismissed.

We also know that outbreaks detected through other means can be missed through syndromic surveillance (e.g., if the system is not tracking the correct events or is limited in geographic coverage). To be effective, a screening tool such as syndromic surveillance must detect outbreaks early and lead to more effective intervention than if the outbreak were detected later. The proportion of relevant outbreaks that syndromic surveillance detects, the extent to which relevant outbreaks have been detected early, and the rate of false alarms remain largely unknown. Furthermore, the benefits of detection through syndromic surveillance, as realized through changes in the course of illness and community health, are currently unknown.

COMPLEXITY OF MEASURING VALUE

The net public health value of syndromic surveillance is particularly difficult to estimate because the scenarios under which syndromic surveillance is intended to perform are numerous, no standard reference exists for comparing the costs and benefits of early detection, and there are additional benefits to syndromic surveillance that must be weighted with the primary purpose for which these systems are being developed: bioterrorism preparedness.

Outbreak scenarios of interest for detection are plentiful and diverse, and approaches that work well or poorly in one scenario might perform dramatically differently in another scenario. Different disease agents vary in the time between exposure and onset of symptoms, the rate of progression to serious complications, the infectiousness needed to transmit to other persons, and the severity of illness. The exposed population also can vary according to its members' existing immunity to illness, numbers exposed, and ways that they manifest disease (e.g., usual patterns of seeking health care).

The environment varies from outbreak to outbreak also, whether in the mode of exposure (e.g., aerosol or water), the intensity of exposure as reflected in the infection rate, the spatial distribution of exposure, or the accessibility of health care resources. The numerous variables that differ between scenarios make drawing conclusions about individual performance factors difficult (e.g., minimum event size detectable or acceptable signal-to-noise ratios) until more systematically collected data regarding experiences are available or valid simulations have been developed in which the multitude of variables can be controlled and modified. Performance evaluation with naturally occurring outbreaks requires common terminology and measurement that permits the factors affecting detection to be expressed clearly. Systematic description of the range of outbreak types, mechanisms and timing of detection, and outcomes[50] can then be accrued over time to draw tentative conclusions. Alternatively, simulations can allow for the control and modification of these factors to study system performance across a range of common scenarios. Simulations, however, are limited in their ability to mimic the diversity and unpredictability of real-life events and by the information currently available regarding the interactions among agent, host, and environmental factors in an outbreak scenario.

Another factor complicating the estimation of value is the lack of a standard method to compare the costs and benefits of syndromic surveillance against alternative detection mechanisms. Comparing the performance of syndromic surveillance to legally mandated disease reporting or telephone consultations with public health authorities is difficult because we do not have a standardized way to monitor these systems for false alarms, missed events, or resource usage. Interpreting the performance of a syndromic surveillance system from a single outbreak is also difficult because the systems can be modified to match the community's tolerance for false alarms or missed outbreaks at any point in time. Although this flexibility to modify detection thresholds is a strength of syndromic surveillance, the complexity of drawing conclusions about the value of a system based on performance at any given time is increased.

Fortunately, bioterrorist-related events currently are extremely rare. Nearly every event detected by syndromic surveillance systems will prove upon investigation to be something other than an act of bioterrorism.[51] The potential benefit of syndromic surveillance for bioterrorism preparedness is that it can provide a safety net that makes it possible to detect a bioterrorist-related event early so countermeasures can be taken swiftly. Quantifying the utility of early detection is difficult, and the value of such detection might change as events evolve. Additional benefits to continuously running syndromic surveillance systems to detect outbreaks from bioterrorism include the detection of naturally occurring disease outbreaks, practical experience in detection and response through system alarms that are not bioterrorism-related, stronger relationships between clinicians involved in the follow-up investigations of syndromic surveillance alarms and public health practitioners, outbreak control data for monitoring a known outbreak, identifying changing patterns of noninfectious conditions, and reassurance when aberrations are not detected during periods when risk is thought to be elevated. Estimating the utility of each of these additional purposes—which are largely unproven at present, change over time, and must be weighted with the costs and benefits for detection of bioterrorism—is difficult.

WHAT NOW?

Critics have pointed out that syndromic surveillance is incapable of detecting small and geographically dispersed clusters such as the anthrax cases in Fall 2001, that the timeliness of syndromic surveillance data might be overridden by delays from the processing steps needed to confirm an outbreak, and that the investigation of false alarms arising from the low specificity for outbreaks of public health interest could prove costly.[10,48,49,51] The question is not whether syndromic surveillance will detect all instances of bioterrorism, but whether its additional contribution to bioterrorism preparedness is worth the cost.

Before either dismissing syndromic surveillance as a fool's errand or encouraging its widespread use based solely on its promise, we must invest in research and evaluation to understand the costs and benefits relative to other public health endeavors. Public health surveillance is a science-based practice, and although science supports the generation of hypotheses based on theoretical knowledge and inference, one cannot test hypotheses without data. What is needed next is to move from holding largely theoretical discussions regarding the potential merits of syndromic surveillance to the point that we have sufficient data to estimate the value of such surveillance accurately.

Many advances are needed in our understanding of systems and outbreak characteristics to improve the ways that we measure performance.[52,53] This body of knowledge will require both careful evaluation of systems in real-life comparisons as well as research based on modeling and simulation and will depend on research partnerships with state and local public health agencies, academic research institutions, private sector interests, and federal agencies. Important research needs include the following:

1. Research is needed to understand the personal health and clinical health care behaviors that might serve as early indicators of priority diseases and allow us to detect outbreaks more accurately and quickly for more effective public health action and to simulate outbreaks more accurately for testing system performance.[54]
2. Exploration of novel types of data is needed to establish their availability and completeness for detecting outbreaks, to determine the proportion of signals that are true events, and to improve the ways that we transform data for analysis (e.g., case definitions) to optimize the balance between detecting all outbreaks and responding to false alarms.
3. Refinement of analytic methods is needed to improve pattern recognition and integration of multiple streams of data so that outbreaks can be detected from background incidence more efficiently (effective simulations and challenge data sets will be important for comparing analytic methods).
4. A shared vocabulary is needed for describing outbreak conditions and tracking the detection experience of alternative surveillance systems so that the real-world experience of different systems under different scenarios can be aggregated and studied systematically for lessons of performance.
5. Methods and tools are needed to uphold public health commitments to privacy and confidentiality in an era of electronic records, and for balancing the needs for security and availability of systems to support their public health functions.
6. Evaluation research is needed, including the cost-effectiveness of different surveillance models for early detection.[12,16,55]

Ultimately, each of these research and development objectives supports the goals of refining surveillance system performance and establishing the value of syndromic surveillance for early outbreak detection when compared with other public health investments.

A recent Institute of Medicine study, *Microbial Threats to Health*, was supportive of syndromic surveillance: "[S]yndromic surveillance is likely to be increasingly helpful in the detection and monitoring of epidemics, as well as the evaluation of health care utilization for infectious diseases." At the same time, the study added, "A balance should be sought between strengthening what is known to be helpful (e.g., diagnosis of patients with infectious illness, strengthening of the liaison between clinical care providers and health departments) and the exploration and evaluation of new approaches."[55]

Syndromic surveillance appears to be strengthening the liaison between clinical care providers and health departments, even in the absence of proven effectiveness for timely outbreak detection, by establishing the role of the local health department in community health and public safety. The increased attention to epidemiological investigation of new types of data in a time-pressured way is invigorating the practice of public health at the local level by providing new "vital signs" of community health relevant to health care and public health. This interaction has extended appreciation for the role of local public health and has facilitated communication between clinical medicine and public health. Improved data sharing and communications should support both early outbreak detection and the other purposes of public health surveillance.

There is no question that there are economic costs to syndromic surveillance as well as opportunity costs in the public health activities deferred to conduct syndromic surveillance; however, the range of benefits that keep local public health departments engaged in this activity needs to be valued. Skillful investment is needed to further explore innovative surveillance methods for early outbreak detection and share findings in a standardized way to establish the experience base from which we can appreciate the added value of syndromic surveillance to the practice of public health surveillance.

ACKNOWLEDGMENTS

This manuscript benefited from the thoughtful review and input of Richard S. Hopkins, MD, MSPH (Epidemiology Program Office, CDC), the editorial support of Jeffrey Sokolow, MA, and the input and reference research of Van Tong, MPH (Epidemiology Program Office, CDC; annotated bibliography available at http://www.cdc.gov/epo/dphsi/syndromic/index.htm).

The scholarly exchange of an expert panel convened by CDC to develop a framework for the evaluation of syndromic surveillance systems also contributed to the articulation of concepts in this article, particularly the participation of James W. Buehler, MD (Center for Public Health Preparedness and Research and Department of Epidemiology, Rollins School of Public Health, Emory University), Louise Gresham, PhD, MPH (San Diego Health and Human Services), Richard S. Hopkins, MD, MSPH (CDC), Ken Kleinman, ScD (Harvard Pilgrim Health Care), Farzad Mostashari, MD, MSPH (New York City Department of Health and Mental Hygiene), J. Marc Overhage, MD, PhD (Indiana University School of Medicine), Julie Pavlin, MD, MPH (Walter Reed Army Institute of Research), Robert Rolfs, MD, MPH (Utah Department of Health, assigned from the National Center for Chronic Disease Prevention and Health Promotion, CDC), Henry Rolka, RN, MPS, MS (Epidemiology Program Office, CDC), and David Siegrist, MS, MA (Potomac Institute for Policy Studies).

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Published online: December 3, 2003