The Next Public Health Revolution: Public Health Information Fusion and Social Networks

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Social, political, and economic disruptions caused by natural and human-caused public health emergencies have catalyzed public health efforts to expand the scope of biosurveillance and increase the timeliness, quality, and comprehensiveness of disease detection, alerting, response, and prediction. Unfortunately, efforts to acquire, render, and visualize the diversity of health intelligence information are hindered by its wide distribution across disparate fields, multiple levels of government, and the complex interagency environment. Achieving this new level of situation awareness within public health will require a fundamental cultural shift in methods of acquiring, analyzing, and disseminating information. The notion of information ''fusion'' may provide opportunities to expand data access, analysis, and information exchange to better inform public health action. (*Am J Public Health.* 2010;100:1237–1242. doi:10.2105/AJPH.2009.180489)

Internet-based technologies (e.g., social-networking Web sites, wikis, and blogs) have led to an explosion in social networks that harness the "wisdom of crowds," giving Internet users convenient instant access to information and communities.[1] These new tools and novel information sources are also becoming ubiquitous in our increasingly wired (and wireless) society, such that members of the general public can readily disseminate their own interpretations of public health events outside a public health context or scientific framework. As these developments make clear, an information revolution is overdue in public health, particularly in epidemiology and surveillance (i.e., biosurveillance), where there is an increasing need to develop, "fuse," and share critical health information for decision-making across numerous fields, communities, professions, organizations, institutions, and health systems. Public health epidemiology and surveillance that are conducted through an electronic medium (chiefly the Internet)—termed "infodemiology" and "infoveillance," respectively—present good opportunities for practice and research.[1] Public health also confronts an increasing proliferation of novel electronic surveillance approaches and multiple legacy data systems amid growing concerns about appropriateness of data release, data validity, and costs versus benefits.[2,3] Although more information now exists electronically than ever before, there is no guarantee that electronic information can be successfully exchanged; in addition, the exchange of electronic information can still be constrained by organizational boundaries erected in response to technical, legal, and privacy concerns.[4]

In recent years, it has become evident that public health events can threaten our national security. Bioterrorism poses an obvious threat to health and life, but any public health event might weaken public confidence in a government's ability to respond to emergencies, undermine a nation's social order, catalyze regional instability, or cause adverse economic impact, including trade restrictions.[5] The worldwide response to the 2009 pandemic influenza (H1N1) outbreak was a prime example of the need for rapid exchange of public health information.[6] Similar recent examples include the SARS (severe acute respiratory distress syndrome) epidemic that spread from China in early 2003 in a matter of days and was associated with local transmission in 4 additional countries, with an economic impact of at least \$50 billion[7]; the largest US foodborne disease outbreak of *Salmonella* Saintpaul in history, with an estimated \$100 million loss to the tomato industry in 2008; and an outbreak of foot-and-mouth disease in Great Britain in 2001, with a tourism industry loss of £2.7 to £3.2 billion and a loss to agriculture and the food industry of £3.1 billion (equivalent to 0.2% of Great Britain's gross domestic product).[8] A typical pandemic of influenza in the United States is estimated to result in 89 000 to 207 000 deaths and economic costs of \$71.3 to \$166.5 billion, excluding disruptions to commerce and society.[9]

To identify novel risks and address extant threats, the United States must implement a nationwide biosurveillance capability that connects domestic and international surveillance systems to provide early warning and ongoing characterization of disease outbreaks in near–real time.[10] Comprehensive biosurveillance ideally would use multiple modalities of information collection, analysis, and dissemination, as well as secure yet flexible information architecture. In addition, strengthening existing surveillance networks and infrastructure, enhancing clinician awareness and participation in biosurveillance, and strengthening laboratory diagnostic capabilities and capacity would result in potential threats being recognized as soon as possible. Integration of routine surveillance information with other potential indicator sources (e.g., health care, veterinary care, agriculture, meteorology, environmental protection, and intelligence) may provide a more comprehensive picture of community health and environmental threats.

DEFINING BIOSURVEILLANCE

On December 18, 2006, the Pandemic and All-Hazards Preparedness Act (SB 3678) was passed, amending the Public Health Service Act to improve situation awareness in public health emergencies. Specifically, the Act recommended,

> In collaboration with State, local, and tribal public health officials, [the secretary of the Department of Health and Human Services] shall establish a near real-time electronic nationwide public health situational awareness capability through an interoperable network of systems to share data and information to enhance early detection of, rapid response to, and management of, potentially catastrophic infectious disease outbreaks and other public health emergencies that originate domestically or abroad.[10]

More recently, Homeland Security Presidential Directive 21 (HSPD-21) required the Department of Health and Human Services to establish a nationwide biosurveillance system predicated on state and local capabilities.[11] This directive defined biosurveillance as the process of "active data-gathering, analysis, and interpretation of biosphere data related to disease activity and threats to human and animal health to achieve early warning, detection, and situational awareness."[8] In response to this directive, the Centers for Disease Control and Prevention (CDC) tasked its newly formed Biosurveillance Coordination Unit with drafting a national biosurveillance strategy for human health in collaboration with federal agencies and state, local, territorial, and tribal stakeholders.[12]

The Biosurveillance Coordination Unit refined the working definition of biosurveillance and enlarged its scope to assess current nationwide capability. The unit defined biosurveillance as the collection and integration of timely health-related information for public health action. This collection and integration is to be achieved through early detection, characterization, and situation awareness of exposures and acute human health events of public health significance. The scope of biosurveillance is all hazards of public health significance, which includes threats and exposures (e.g., disease in animals with zoonotic potential, environmental exposures, natural disasters, and terrorism events), adverse events, instances of diseases (e.g., nationally notifiable diseases), and outbreaks. Biosurveillance capability is distributed across local and state jurisdictions and is supported and complemented at the federal level, providing value on a global scale. Biosurveillance relies upon structured public health surveillance systems, the use of nonstructured data and non–public health information sources, and information generated from epidemiologic investigations, and it is highly dependent on a skilled workforce.[12]

These definitions of biosurveillance are consistent with similar efforts on the part of the European Centre for Disease Prevention and Control to integrate and coordinate the development of early warning and response capabilities to meet new challenges, including implementation of the 2005 International Health Regulations.[13] The International Health Regulations are an internationally binding legal instrument designed to help the international community prevent, report, and respond to acute public health risks that have the potential to cross borders and threaten people worldwide. The European Centre for Disease Prevention and Control has defined "epidemic intelligence" as encompassing all activities related to early identification of potential health hazards, including the functions of public health surveillance (both structured and unstructured) and epidemiologic investigation, with the goal of recommending public health control measures.[14,15] In all efforts to strengthen integrated biosurveillance capabilities, it is critical to use a systems-based approach and to make wise investments in new technologies that build on current capabilities and efforts.[12,16]

This "system of systems" biosurveillance capability must be able to identify specific disease incidence and prevalence in heterogeneous populations and environments and must possess sufficient flexibility to tailor analyses to new syndromes and emerging diseases. State and local government health officials, public- and private-sector health care institutions, and practicing clinicians must be involved in biosurveillance system design, and the overall system must be constructed with the principal objective of establishing or enhancing the detection and response capabilities of state, territorial, tribal, and local government entities. Priorities for biosurveillance investment in the United States have been outlined in the Pandemic and All-Hazards Preparedness Act[10] (see the box on this page).

PRIORITY AREAS FOR US BIOSURVEILLANCE INVESTMENT

- Electronic health information exchange
- Electronic laboratory information exchange
- Unstructured data collection and analysis
- Integrated biosurveillance information
- Global disease detection and connectivity
- Biosurveillance workforce for the future

Note. Adapted from the Pandemic and All-Hazards Preparedness Act.[10]

APPLYING THE CONCEPT OF "FUSION" TO PUBLIC HEALTH

Since September 11, 2001, the intelligence community has become a pioneer in creating information-sharing environments that capitalize on new intelligence methodologies and, more importantly, that foster a culture of sharing information.[17] Innovation in methods of information integration and exchange is also occurring at the 70 "fusion centers" located in every US state and many major cities; the Department of Homeland Security and the Department of Justice recognize these centers as critical elements supporting situation awareness.[18] Fusion centers vary in function and capacity, but in general they serve as environments that facilitate data collection and the exchange of information across programs.[19] Fusion centers are designed to provide broader access to disparate data and to integrate and complement existing data streams.[20] Many are staffed by multiagency personnel across levels of government and jurisdictions, and some include collaborators in the private sector.[20] However, fusion centers require evaluation, and best practices for fusion centers continue to be developed.[21]

To address the need for integration and exchange of biosurveillance information and to develop ways to access and use unstructured data, the CDC implemented a pilot program called BioPHusion, which tested the operational capacity of a public health fusion center. The goal of this program, launched in July 2008 and completed in July 2009, was to examine the utility of biosurveillance integration and exchange, and potentially to create best practices for a national network of state and local public health fusion centers (Figure 1). Public health fusion centers would support and enhance current capabilities to collect, analyze, and exchange interpreted biosurveillance data (i.e., information) from existing traditional systems and nontraditional sources. Fusion centers also would provide mechanisms for disseminating information to decision makers.

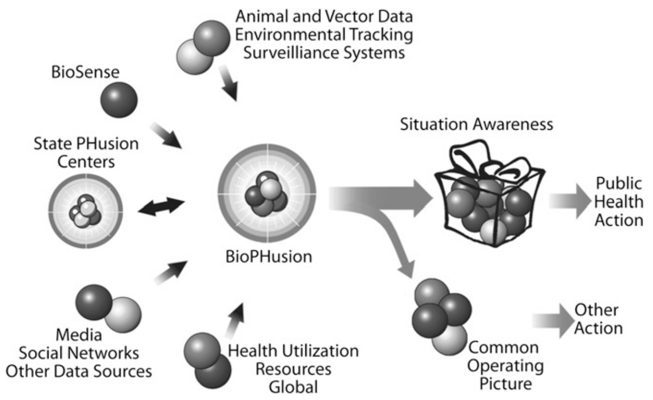


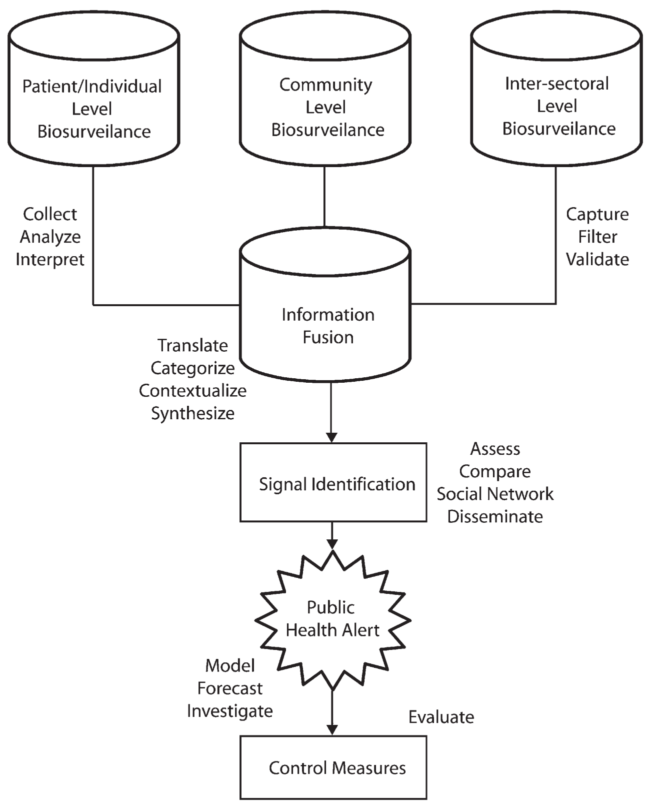
FIGURE 1—The BioPHusion pilot program of the US Centers for Disease Control and Prevention.

Biosurveillance information can be broadly categorized in a number of different ways: information on exposure, morbidity, and mortality at the patient or individual level; health indicator and health utilization information at the community or population level; and intersectoral information from sources outside public health (e.g., animal health, environmental monitoring, food distribution, and law enforcement; Figure 2). Biosurveillance information fusion currently rests in the hands of analysts and requires diversified subject-matter knowledge to translate, contextualize, and synthesize information across categories for meaningful dissemination to stakeholders through alerting mechanisms. However, information–fusion algorithms are being investigated as ways to use multiple data streams[22] and clinical decision support systems[23] to add population-based, public health–focused decision support to current outbreak detection–focused systems.

The BioPHusion network was intended to specifically allow for alert verification and dissemination by routinely collecting, monitoring, and synthesizing disparate kinds of health information into actionable knowledge in order to support public health action. The program was designed to help maintain situation awareness and provide a "common public health operating picture" (e.g., epidemic intelligence).[15,24] In addition, BioPHusion was designed to be a source of interpreted, fused public health information for use by other federal agencies, including the Department of Homeland Security, which is charged with national biosecurity. Enhancing early detection of, rapid response to, and effective management of potentially catastrophic infectious disease outbreaks and other public health emergencies will require a bottom-up knowledge-management approach that synthesizes information within global, federal, state, territorial, tribal, and local programs. This concept of multidirectional information flow would rely heavily on the creation of new electronic social networks for knowledge management.[25,26]

THE SCOPE OF FUSIBLE BIOSURVEILLANCE INFORMATION

Public health entities are using nontraditional unstructured and open-source data sources to complement and enhance traditional surveillance systems. Although these data sources present unique biosurveillance opportunities, their validity and usefulness require continued examination. Tools such as the Global Public Health Information Network (GPHIN), HealthMap, EpiSpider, ARGUS, and Google.org Flu Trends mine low-cost,



Note. Modelled from Paquet et al.[14]

FIGURE 2—Conceptual model of a distributed biosurveillance information fusion framework.

unstructured data for event-based information. These data sources include news wire services, listservs, ProMED-mail, online newspapers, and search engines.[27–30] GPHIN, developed by Health Canada and adopted by the World Health Organization, created revolutionary new possibilities for global outbreak response by using news media information for earlier event detection, eschewing the pyramid of official reporting and disregarding national boundaries of outbreak notification.[31] By incorporating news within the emerging apparatus of global infectious disease surveillance, GPHIN enhanced the effectiveness and credibility of international public health and improved traditional national disease reporting.

Similarly, the publicly available Google.org Flu Trends analyzes large numbers of Google search queries to track influenza-like illness in a population.[32] Because the relative frequency of certain queries is correlated with the percentage of physician visits in which a patient presents with influenza-like illness, search engine queries may be able to estimate the current level of weekly influenza activity in each region of the United States, with a reporting lag of approximately one day. The response to the 2009 influenza pandemic (H1N1) showcased the power of Web 2.0 technologies for communications purposes because the CDC and other entities have used blogs, widgets, wikis, microblogs (e.g., Twitter), RSS (real simple syndication) feeds, and podcasts for communication with other public health officials, the health care industry, and the public.[33]

News media reports and search engine queries are just two of many such sources of low-cost electronic information that can be used to benefit the public health need to improve detection, response, and prediction. Near–real time detection and event characterization will also likely benefit from the increasing availability and automated analysis of electronic health records.[34] There is a need for an interoperable public health surveillance system that will allow exchange of information (consistent with current law) between provider organizations, contracting organizations, and local, state, and federal agencies.[35] BioSense, the CDC's national, electronic, hospital-based syndromic surveillance system, is piloting methods to access and analyze electronic medical records for disease surveillance and event monitoring. These novel methods that capitalize on unstructured open-source data and electronic health records are expanding the scope of available information, but biosurveillance is still anchored in efforts to strengthen existing systems and capabilities. Existing systems include environmental monitoring, animal disease surveillance, reportable (notifiable) disease surveillance, laboratory surveillance, and laboratory networks. Many of these systems are underfunded and are maintained within disparate programs at all levels of government; consequently, they often lack the ability to readily exchange information.

CHALLENGES

Effective fusion of multiple, disparate, and often unstructured and overwhelming streams of data will require the development of new tools and a new cadre of trained public health information analysts, epidemiologists, and informaticians. Improved tools for information formatting and integration, data acquisition, data characterization, information extraction, data mining, and decision-making are needed.[27] The workforce supporting a nationwide public health fusion network must acquire and maintain the skills needed to: (1) collaborate with information providers to validate and verify information (assess "signals" detected in data), (2) understand the context of this information and the likelihood of the event in question, (3) assess event magnitude (morbidity, mortality, geographic distribution, and population at risk), (4) evaluate the credibility of the information sources, and (5) provide audiences with a standardized interpretation of event likelihood, event magnitude, and information credibility. A public health biosurveillance workforce lacking adequate training, preparation, and regularly upgraded skills could impair biosurveillance and public health response efforts.[36]

Web-based social networks that are freely available, easy to use, and lack oversight by authorities can foster an information environment that includes biased or erroneous information that could result in harm to individual or community health.[37] As a result, information sources will need to be assessed and prioritized on the basis of their potential value and relevance for detecting emergent public health events and enhancing situation awareness. A unique challenge will be to develop enhanced analytic and information validation methods that increase the sensitivity of signal detection without increasing the alert rate[34] (a primary criticism of syndromic surveillance). This requires a focus on decision-making, establishing analytic techniques for qualitative information versus quantitative data (e.g., triangulation, a method used in qualitative research),[38] and developing strict classification criteria for alerting (e.g., define public health threat classification and scale). An openness to new data sources and dynamic information streams as the underpinning of biosurveillance should also permit the use of forecasting methods and modeling to describe potential scenarios, for true situation awareness.[24] Participants in new electronic social networks within public health could serve as distributed analysts who assess and verify this information and develop their own connections and interpretations.

The real challenge, however, is not to develop new tools or increase access to existing electronic information; rather, it is to cultivate new public health social networks of professionals at the local, state, and federal levels. These networks could serve as sources of qualitative data on health events and situation awareness; as environments for distributed investigation, validation, analysis, and interpretation of information for potential actionable associations; and, ultimately, as sources of timely action to prevent and decrease morbidity and mortality. The value of such social capital is well established.[39] A Web-based social-network site would allow individuals to construct a public or semipublic profile within a bounded system, articulate a list of other users with whom they share a connection, and view and traverse their list of connections and those made by others within the system.[40] Embedded resources in social networks enhance information flow, exert influence, certify social credentials, and reinforce a person's worthiness both as an individual and as a member of a group. A social-network site is also an excellent way to foster collective intelligence activities among individuals with public health interest across various domains, improving public health group cognition, coordination, and cooperation.[20] Such networks are actively encouraged in business and industry, where they have already been empirically proven to provide broader access to diverse, novel information to improve group performance.[41,42]

There also is a significant need to cultivate a public health culture that is open to secure and timely sharing of information, in contrast to the current environment, which is mired in emphases on data ownership and privacy concerns. To address cultural barriers to information sharing, any new information revolution within public health must add value to all the components of the distributed public health system, including such sectors as health care, industry, agriculture, and academia. Information sharing will be enhanced by paying attention to legitimate issues of information security by ensuring information confidentiality, integrity, authentication, and availability. To assess information reliability resulting from fusion activities and the impact of enhanced biosurveillance capacity and capability, process standards and surveillance evaluation indicators must be defined and routinely monitored.

Securing the health of our nation depends on near–real time access to actionable, "fused" health intelligence. To ensure this access, we must collectively improve our disease detection, alerting, and prediction capabilities. The Internet revolution, increased availability of electronic heath-related information, and improved information technology have given public health practitioners unprecedented access to novel streams of information and the ability to establish social networks for analysis and dissemination. Capitalizing on this opportunity will require the public health community to change its organizational culture so that the uses of information are not limited to traditional surveillance and direct notification. Instead, we must collectively learn to share information, reward the sharing and reuse of information across domains, and expand the boundaries of public health to multiple new sectors. ■

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Note. The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention.

Human Participant Protection

No protocol approval was needed because no human research participants were involved.

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