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Donald A. Donahue Jr., *Potomac Institute for Policy Studies*

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BioWatch and the Brown Cap

Donald A. Donahue Jr.

Abstract

The United States has invested significant resources toward creating a surveillance capability that can detect emerging diseases or acts of bioterrorism. While this is a timely pursuit — the WHO states new diseases are being detected at an unprecedented rate — the effort remains disjointed and oriented toward "high-tech" solutions, often at the expense of potentially readily apparent solutions. This article examines extant surveillance efforts and proposes that a more mundane approach to biosurveillance may actually be more productive.

KEYWORDS: biosurveillance, emergency preparedness

The optimal approach to detecting emerging diseases may follow Harry Shipman. Shipman was the central character within a parable told in the 1988 romantic comedy, *Crossing Delancey*. A story within a story, the parable is presented at an awkward moment during a blind date. Isabelle Grossman (played by Amy Irving) lives on Manhattan's Upper East Side, where she partakes in and pursues the "uptown:" a sense of sophistication, interacting with the intelligentsia, and embracing high technology. Her date, Sam Posner (Peter Riegert), owns a pickle shop on Essex Street, below Delancey on the Lower East Side.

As the awkwardness grows, Grossman explains this is not her world. Posner responds with the tale of a friend who finds his future wife after losing his favorite brown cap. This prompts Grossman to comment on the remarkable find of a fiancé due to a lost cap. As the pickle merchant tells it: "Oh, he had his eyes on her for a long time, but she couldn't see him. The little brown cap…. She couldn't see his eyes" (Nozik and Silver, 1988). In other words, the answer was in plain sight for both, if each had the wisdom or inclination to look.

In many ways, our national effort to detect biological outbreaks is akin to the fictional Shipman's brown cap search for a mate. We focus on technological detection and empirical validation when more subtle indicators may offer earlier evidence of an emerging outbreak. Medical science is uncomfortable with predicting future events without the benefit of detailed analysis of extensive data sets steeped in the scientific method and rigorous empirical standards for validation within a Cartesian discipline. Yet the mandate for earlier—almost intuitive—detection of a naturally emerging or human-introduced pathogen remains strong.

A Growing Need

New disease threats

> appear to be emerging more quickly than ever before. Since the 1970s, new diseases have been identified at the unprecedented rate of one or more per year. There are now nearly 40 diseases that were unknown a generation ago. In addition, during the last five years, WHO has verified more than 1100 epidemic events worldwide (WHO, 2007, p. x).

Surveillance by the World Health Organization (WHO) reveals that the emergence of a novel disease is not a localized phenomenon. As illustrated in Figure 1, new outbreaks have been recorded in less than a decade on every continent save Antarctica, in all climates, and across all cultures, from highly developed nations to emerging states.

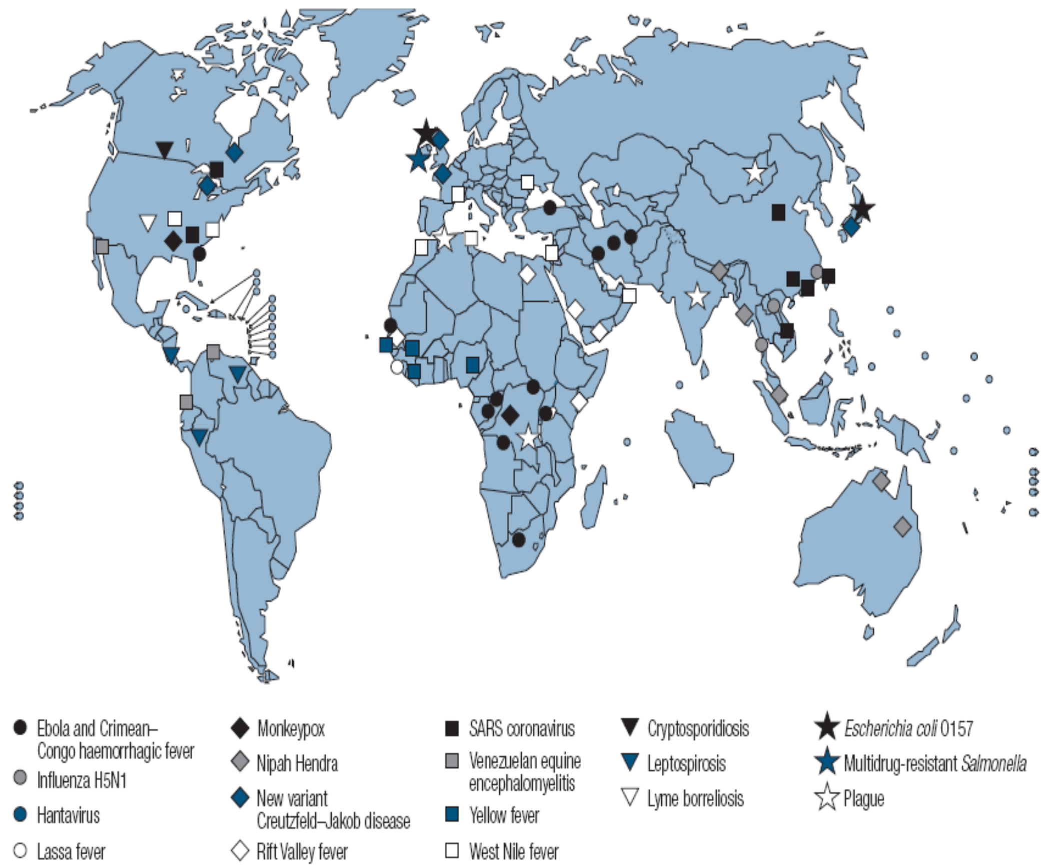
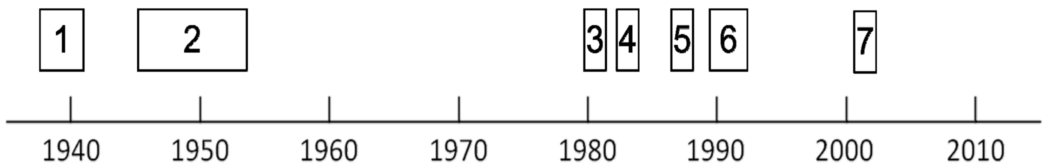


Figure 1. "Selected Emerging and Re-emerging Infectious Diseases: 1996–2004" (WHO, 2007, p. 12).

Simultaneously, the specter of epidemic as an act of malevolence has moved from the speculative to reality. Cronin (2002/2003) documented seven acts of bioterrorism over the past seventy years. Plotting these against a time line reveals increasing frequency clustered in the latter half of this time span, as indicated in Figure 2.



Key:

1. 1940–41: Japanese use biological warfare in Hangzhou and Nanjing provinces of China
2. 1957–63: Bioterrorism used in Brazil against tribal populations
3. 1981: Commandos use anthrax against a research facility in the United Kingdom
4. 1984: Rajneeshee cult members contaminate salad bars in Oregon with salmonella
5. 1989: Bioterrorism used in Namibia during covert operations by South Africa
6. 1990–93: Aum Shinrikyo cult members use a variety of agents, including anthrax, against government and other targets in Japan
7. 2001: Anthrax-laden letters are mailed through the U.S. postal system

Figure 2. State and Nonstate Use of Biological Warfare

The growing recognition of the threat posed by a novel disease or the willful introduction of a contagion as a weapon of warfare or terrorism has resulted in myriad initiatives to identify such an event. Methods being used or explored include syndromic surveillance, sentinel surveillance, environmental monitoring, and retrospective laboratory or epidemiologic analysis. These approaches focus on the incidence of disease in humans. Reports of dead animals and veterinarian disease surveillance data have been shown to be applicable to human epidemiology as well (Eidson et al., 2001). There has yet to emerge a widely accepted means of identifying and assessing relevant indicators and risks.

A Centers for Disease Control and Prevention (CDC) Working Group in 2004 discussed the pathway toward creating the capability to identify emerging disease outbreaks:

> Early detection of outbreaks can be achieved in three ways: 1) by timely and complete receipt, review, and investigation of disease case reports, including the prompt recognition and reporting to or consultation with health departments by physicians, health-care facilities, and laboratories consistent with disease reporting laws or regulations; 2) by improving the ability to recognize patterns indicative of a possible outbreak early in its course, such as through analytic tools that improve the predictive value of data at an early stage of an outbreak or by lowering the threshold for investigating possible outbreaks; and 3) through receipt of new types of data that can signify an outbreak earlier in its course (Buehler et al., 2004).

Missing the Obvious?

This “new type of data” is precisely what is needed here. The irony is that new data already exist. The need now is actually the information and knowledge that must be synthesized from those data. Consider the identification of the emergence of West Nile virus (WNV) and severe acute respiratory syndrome (SARS).

A flavivirus hitherto unrecognized in the Western Hemisphere appeared in New York at the cusp of the millennium (CDC, 2007). WNV was first observed in the United States in the New York metropolitan area during the summer of 1999. In 1999–2000, there were more than sixty cases of confirmed WNV-associated disease and six fatalities in the New York area. In 2001, sixty-six cases of human West Nile disease were reported, including nine fatal cases. During the summer of 2002 there was a dramatic increase in activity in the United States with evidence of WNV reported in forty states. More than 4,000 laboratory-confirmed cases were reported to the CDC, with 284 deaths attributable to WNV (O’Leary et al., 2002).

Initial identification of the disease came on August 23, 1999, when “an astute physician in Queens, NY recognized that it was unusual to have 2 cases of febrile encephalitis at the same time within a very small area of one neighborhood” (University of Wisconsin–Madison School of Veterinary Medicine, n.d.). The original suspicion—that the new disease being seen by physicians was not St. Louis encephalitis (Fine and Layton, 2001), as had been suspected, but rather something else—was raised not by the public health surveillance system but by Dr. Tracey McNamara, head pathologist at the Bronx Zoo, who provided a specimen for analysis to a friend at the U.S. Army Medical Research Institute in Infectious Diseases in Fort Detrick, Maryland (American Museum of Natural History, n.d.).

Similarly, the emergence of the novel coronavirus, which came to be known as SARS, was identified in the Western world by a retired U.S. Navy infectious disease investigator responding to an informal e-mail correspondence from a colleague in Guangdong Province (Soares, 2003). The initial alert to the Western medical community did not emanate from the official communication channels of WHO, the CDC, or any government agency, but rather from within the open Program for Monitoring Emerging Diseases (ProMED) online community sponsored by the International Society for Infectious Diseases.

In both of these instances, the intuition of individual practitioners observing seemingly unrelated phenomena proved to be the catalyst for accurate identification of the disease. Because these events were relatively localized, it was possible to identify infections close to the index case and to design effective countermeasures. This may not have been possible, however, had the disease been introduced purposefully in multiple locations, thereby circumventing its natural epidemiological dispersion pattern. The ability to detect anomalies, therefore, will be critical to the timely identification and mitigation of evolving pandemics.

Enter Technology

Data mining and risk analysis have achieved significant levels of sophistication. Financial organizations are able to predict the probability of default with "Six Sigma" levels of accuracy. Department of Veterans Affairs researchers can project the likelihood of an individual veteran becoming homeless (Karney et al., 2008; Rosenheck and Fontana, 1994; Tollett and Thomas, 1995). Following Hurricane Katrina, an ad hoc consortium coordinated the assembly of prescription drug information for 800,000 evacuees via KatrinaHelp.org (Stevens, 2005). Yet this analytical capability has yet to be applied to the issue of domestic medical intelligence.

The dawning of the twenty-first century brought with it several sentinel events that pointed to the need for a greater ability to detect emerging medical threats. These events represent threats that "require urgent action" according to WHO: "Recent history shows that some of the most serious threats to human existence are likely to emerge without warning" (WHO, 2007, p. xii). Early identification facilitates interventions that can stem the spread of disease.

In many ways, this search for risk indicators resembles those searches developed for other threats, such as terrorism or financial crimes. One significant departure, however, is that surveillance for signs of an emerging disease need not result in individual identification. This precludes privacy issues that resulted in the curtailment or cancellation of programs such as KatrinaHelp.org (Stevens) or the Department of Homeland Security Analysis, Dissemination, Visualization, Insight, Semantic Enhancement (ADVISE) program (GAO, 2007).

The value of open-source intelligence as a risk predictor and mitigation tool for government and business is evidenced both by the emergence of a fledgling industry and by the acknowledgment of the capabilities therein. An Internet search of the term "open source business intelligence" returns 64,300 results, the first several pages of which focus on software products, business intelligence services, and analyses. The Open Source Challenge, an annual contest sponsored by the Office of the Director of National Intelligence, challenges industry to generate valid conclusions and actionable intelligence that are based on generally available data. The increasing sophistication of the results prompted the creation of the National Open Source Enterprise under the direction of the director of national intelligence (2006).

The very nature of disease progression offers latent evidence of its existence. Diseases affect daily activities, which can be examined for trends indicative of an underlying pathology. Illness can prompt increases in sales of over-the-counter (OTC) products: analgesics, antihistamines, and cold relief medications. Illness causes changes in mass transit ridership and commuter patterns, which can be evidenced in toll bridge or road receipts. Examination of targeted absenteeism reports and school attendance can indicate disease progression patterns.

So Many Choices, So Little Time

Several extant systems search for evidence of emerging diseases, albeit in a largely retrospective, diverse, and nonintegrated manner. A brief review of their scope and capabilities is illustrative with regard to analytical and functional integration, or lack thereof.

The U.S. Outpatient Influenza-Like Illness Surveillance Network (ILINet) is a passive influenza surveillance project coordinated by the CDC. ILINet serves as a central repository for influenza surveillance data drawn from two sources: morbidity information voluntarily submitted by providers and virologic reporting from approximately 150 participating laboratories (CDC, n.d.).

The CDC also coordinates the Public Health Information Network (PHIN) in conjunction with the National Association of County and City Health Officials and the Association of State and Territorial Health Officials. PHIN focuses on five functional areas: early event detection, outbreak management, connecting laboratory services, partner communications and alerting, and countermeasure/ response administration. Within PHIN, the National Electronic Disease Surveillance System promotes the use of data and information system standards to advance the development of efficient, integrated, and interoperable surveillance systems at federal, state, and local levels.

The National Retail Data Monitor (NRDM) was developed at the University of Pittsburgh as a public health surveillance tool to collect and analyze daily sales data for OTC health care products. NRDM collects these data for selected products in near real time from more than 15,000 retail stores and makes the data available to public health officials (Wagner et al., 2004).

Also developed at the University of Pittsburgh, the Real-time Outbreak and Disease Surveillance (RODS) Laboratory is an electronic public health surveillance system deployed in California, Michigan, New Jersey, Ohio, Pennsylvania, Texas, Utah, and Taiwan. The laboratory collects data from existing computer systems in clinical and other settings and displays them for public health departments through a secure web-based user interface (Fairchild et al., 2007).

BioWatch was fielded by the Department of Homeland Security (DHS) “to detect the release of pathogens into the air, providing warning to the government and public health community of a potential bioterror event” (Shea and Lister, 2003). While many of the details of BioWatch are not for public consumption, the program reportedly uses existing Environmental Protection Agency air quality monitoring stations in some thirty U.S. cities to collect samples by passing ambient air through filters; the air samples are then regularly analyzed at state and local public health laboratories.

The Department of Defense (DoD) conducts active global surveillance for infectious diseases that might affect military personnel and their departments (Department of Defense, 2005). The Global Emerging Infections Surveillance and Response System (GEIS) links DoD laboratories, research facilities, and the military health system to facilitate rapid recognition and response to protect national security and the health of the forces. GEIS conducts clinical and laboratory surveillance for emerging diseases as well as for specific diseases such as influenza and other respiratory diseases, enteric diseases (e.g., norovirus), acute febrile illness (e.g., malaria), acute hemorrhagic fevers (e.g., dengue fever), antibiotic resistant microbes resistance, and sexually transmitted diseases (DoD, 2005; DoD 2006).

Another DoD program, the Electronic Surveillance System for the Early Notification of Community-based Epidemics (ESSENCE), is a prototype for the early detection of infectious disease outbreaks at military treatment facilities (Lombardo et al., 2003). ESSENCE draws from automated systems that are based on syndromes, examining nontraditional data sources such as ICD-9 (*International Classification of Diseases*) codes, pharmaceutical sales, and emergency department chief complaints (Foster, 2004).

BioSense, developed and hosted by the CDC, is a national web-based biosurveillance program intended to improve capabilities for conducting near real-time biosurveillance, enabling health situational awareness through access to existing data from health care organizations across the country (CDC, n.d.). BioSense monitors diseases that result from bioterrorism, infections like influenza, and other health events related to natural disasters. It functions through the secure transmissions of clinical care data from hospitals to the CDC or a state or local system. The data are then analyzed, interpreted, and displayed through user interface tools that give public health and health care professionals various means of exploring the data sets. The program receives and displays data from more than 1,730 hospitals across the country (CDC, 2009).

Epi-X, the Epidemic Information Exchange, is “the Centers for Disease Control and Prevention's web-based communications solution for public health professionals. Through *Epi-X,* CDC officials, state and local health departments, poison control centers, and other public health professionals can access and share preliminary health surveillance information” (CDC, n.d., “What Is Epi-X?”). Epi-X requires the direct input of information.

The Program for Monitoring Emerging Diseases (ProMED) is the Federation of American Scientists' policy initiative calling for global monitoring of emerging diseases, and its online information exchange, ProMED-mail, supports that initiative (Federation of American Scientists, n.d). ProMED is a moderated, online discussion forum—in essence, a form of social networking.

A geographic information system (GIS)-based program, HealthMap aggregates disparate data sources to achieve a unified and comprehensive view of the current global state of infectious diseases and their effects on human and animal health. The openly available website integrates outbreak data of varying reliability, ranging from news sources (such as Google News) to curated personal accounts (such as ProMED) to validated official alerts (such as from WHO). Through an automated text processing system, data are aggregated by disease and displayed by location for access to the original alert (Freifeld and Brownstein, 2007).

When one system detects an anomaly, will another? Can a comparative assessment be prompted or conducted? Is there an interactive validation mechanism? When identifying an emerging outbreak, time is critical. The earlier a disease can be identified, the quicker prevention and response can be mounted. Integrated analysis is key.

The Way Forward

Despite the existence of multiple mechanisms, the surveillance function continues to be more an aggregation and amalgamation of disparate, observed symptoms than an incorporated analytical process. What appears to be missing is an organic mechanism for integrating, synthesizing, and analyzing different inputs, something that would link data sources to develop a core situational assessment. This would, in turn, serve as the basis for examination, the drawing of a conclusion, and the development of subsequent actions. In the allegorical vignette offered at the opening of this article, diverse inputs were processed within a cognitive-neurophysiological approach—a combined instinctual, emotional, intellectual, and physiological evaluation of physical, cultural, and situational suitability—leading to a conclusion to become engaged. This was only possible once a cognitive obstruction—the brown cap—was removed.

Advances in technology have created tools by which to derive organic indicators and through which to apply human interaction to extrapolate probabilities and test hypotheses. One such technology has been used by federal officials in situations as diverse as contemplating closing the border in advance of an influenza pandemic, managing response to a catastrophic typhoon, and modeling chronic disease conditions (Donahue et al., 2009; Quantum Leap Innovation, 2010). The technology integrates agent-based modeling with a stochastic structured-population susceptible-exposed-infectious recovered (SEIR) model. This hybrid approach has several advantages over pure methods. First, it provides an agent-based, multiscale modeling, simulation, and analysis platform for characterizing a potential pandemic or biological attack—including its cascading consequences on populations, the economy, and the infrastructures at local, regional, and national levels—combined with a low computational overhead of differential (or difference) equations. Second, it deals with the challenges involved in assigning limited resources to address numerous and dispersed critical missions, and in projecting adaptive behaviors of populations in response to various possible interventions. Third, using an analytical, agent-based computational disease modeling and decision support mechanism in a distributed computing technology (cloud-computing) environment offers the potential of a secure, intuitive, Internet service designed for public health professionals to model the dynamics of the spread of a population-level disease. It provides tools and capability to understand disease outbreaks from a continental perspective down to a health official's own backyard.

As a decision-support and resource management tool, this approach can reduce the risk and uncertainty surrounding emerging infectious diseases by allowing public health professionals to examine disease spread and test mitigation strategies within a simulated population. To start, the base simulation can be seeded and configured according to the user's knowledge of the outbreak situation and geographical region. Advanced user interfaces and architecture allow users to examine a simulation in detail with digital video recorder (DVR)-like controls. In addition to running a base simulation, users can simulate and test various intervention strategies (both medical and nonmedical, alone or in combination) and assumptions. The base simulation can be compared and analyzed at any point with other simulations on the basis of tests and changes in assumptions; the comparisons will provide insight as to what effect those interventions and assumptions will have on the outcome.

The ability to modify models and test progression scenarios and countermeasure efficacy is critical to addressing unanticipated outbreaks. The greatest public health challenges derive not from known threats but rather from novel disease outbreaks, the emergence of which creates a period of uninhibited spread between emergence and identification of source and response. Similarly, analytical tools must be able to adjust for differences as events unfold and for variable inputs such as plume height, humidity, wind velocity and direction, and pathogenic characteristics.

The More the Merrier

A decade ago, this author met with the Veterans Health Administration deputy chief information officer, Pete Gruen. Pete observed that the model for both health information technology (HIT) and effective and proactive outbreak surveillance and detection already exists; it is carried virtually universally in the form of a credit card. Through Visa, Master Card, American Express, or another type of credit card, financial transactions made at the far corners of the globe are conveyed to and deposited in banks in the heartland, all in a matter of moments. This distributed financial network with common interface protocols has revolutionized commerce. Health care, however, has largely avoided this level of integration and promoted proliferation of “stovepipe” systems that serve a single function with scant connectivity to other systems. This has limited the expansion of HIT and the effectiveness of disease surveillance. To achieve optimal efficacy, disparate systems must be linked and expanded to include the panoply of potential data sources.

The value of a network is enhanced by the number of its connected users, a phenomenon referred to as Metcalfe's law (Shapiro and Varian, 1999). Metcalfe's law embodies the network effects of technologies such as the Internet, social networking, and the World Wide Web. A single node is useless, but the value of every additional node increases with the total number of nodes in the network because the total number of people and organizations with whom each user may interact increases.

Optimizing of disease surveillance and outbreak detection will require two actions: expansion and diversification of input sources and “democratization” of elements examined. Voluntary input is valuable but narrowed by the limited source universe. Passive surveillance and epidemiological analysis is hindered by being retrospective by definition. Focused scientific analysis offers the promise of technological advances but can often overlook obvious clues. The ability to see evidence “hiding in plain sight” is one we need to develop.

In the coal mines of old, canaries, while not high tech, were extremely efficient. When it comes to the ability to detect the next pandemic or bioterrorism attack, there is no question that science and technology offer tremendous augmentative tools. They may, however, not be the best initial indicators. To maximize lead time and mitigation, perhaps it is time we doffed our biosurveillance brown caps and looked matters squarely in the eyes.

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