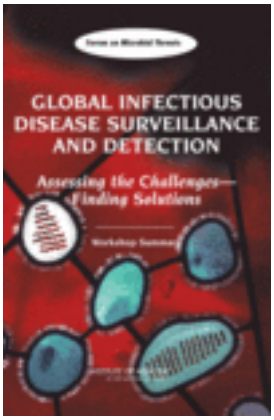

Global Infectious Disease Surveillance and Detection: Assessing the Challenges -- Finding Solutions, Workshop Summary

Forum on Microbial Threats, Stanley M. Lemon, Margaret A. Hamburg, P. Frederick Sparling, Eileen R. Choffnes, and Alison Mack, Rapporteurs

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Resource Needs and Opportunities

OVERVIEW

Following workshop sessions that emphasized technical considerations for infectious disease surveillance, detection, diagnosis, and reporting, the final session focused on relevant issues in public health policy, many of which had been raised in prior discussions.

Global Coordination

The opening presentation, by Will Hueston, of the School of Public Health and College of Veterinary Medicine of the University of Minnesota, describes challenges in coordinating these vital public health activities. In his contribution to this chapter, Hueston adopts a business perspective to analyze key technical and social impediments to coordination. He explores how surveillance might be repurposed as part of a system of disease detection, reporting, and outbreak investigation; then he outlines political, technical, and educational measures that would support such reform. By way of conclusion, Hueston employs business strategic planning analysis to identify strengths, weaknesses, opportunities, and threats inherent in current approaches to addressing infectious diseases.

Following Hueston's presentation, a panel discussion explored diverse perspectives on resource needs and opportunities for infectious disease surveillance, detection, diagnosis, and reporting. William Karesh, who spoke in a previous session about infectious disease surveillance in animals (see Summary and Assessment and Chapter 1), concurred with Hueston's position that surveillance should be designed to answer questions of long-term importance, rather than of present-

day urgency. Noting that "society is healthier because more people understand health," Karesh advocated greater information sharing by public health officials as a way to reduce, rather than increase, panic in response to disease threats, and also to increase popular support for funding public health. He envisioned a two-way exchange of surveillance information, with the global public both supplying essential data and receiving the benefits of its meaningful interpretation.

Panelist James LeDuc, Director for Global Health in the Institute of Human Infections and Immunity at University of Texas Medical Branch, offered a concrete example of the potential for such "grassroots" surveillance: In Cambodia, a network of "semitrained" villagers with cell phones and Mopeds swab sick chickens and ducks to check for avian influenza and alert the health community to suspected human cases. Multinational companies represent another newly tapped source of global surveillance information; LeDuc noted that the Centers for Disease Control and Prevention (CDC) has established collaborations with a number of major companies operating in China, encouraging them to share signs of unusual disease activity. He also identified two recent developments at the World Health Organization (WHO) as significant opportunities for global coordination in addressing infectious disease: the appointment to Director-General of Margaret Chan, who has extensive experience in this area, and the ratification of the revised International Health Regulations (IHRs; see Summary and Assessment).

On Location and in the Lab

In contrast to the global perspective taken by LeDuc, panelists Marci Layton, Fernando Guerra, and Frances Downes offered local viewpoints on infectious disease surveillance and detection. Layton, who had previously discussed local public health surveillance as conducted by the New York City Department of Health and Mental Hygiene (DOHMH; see Summary and Assessment and Chapter 1 overview), reemphasized that public health is an essentially local pursuit, and that its most important asset is its infrastructure, particularly its workforce. While acknowledging advantages in disease detection conferred by the increasing volume of surveillance information available at the local level, she stressed the importance of passing this inevitably noisy data through a "public health filter," embodied in "an epidemiologist looking at the data, a physician interviewing other physicians to find out more deeply about a case, or field staff going out and investigating the case." This process converts raw surveillance data into "trustable" intelligence that avoids being premature or panic inducing, Layton said.

Guerra, Director of Health for San Antonio and Bexar County, Texas, works with a population much smaller than that of New York City, but one that is similarly diverse and changeable. His experiences in building and using surveillance systems, such as an immunization registry and tracking program, reveal the profound influence of social circumstances on public health and their potential contribution to "situational awareness" of disease threats, as discussed in prior

sessions (see Summary and Assessment). The terms of reference for syndromic surveillance need to be broadened, Guerra argued, and in particular should encompass psychosocial and environmental circumstances.

Downes, Laboratory Director for the Michigan Department of Community Health, discussed opportunities for improving infectious disease surveillance from the perspective of the public health laboratory. Her contribution to this chapter, which summarizes her presentation, describes the creation and strengthening of laboratory networks, the removal of barriers to disease reporting by laboratories, the role of information technologies, and the incorporation of syndromic surveillance and disease diagnosis in the field. Given its unique position as "the point at which laboratory science and public health surveillance intersect," the public health laboratory should lead the integration of nontraditional laboratory surveillance sources into public health surveillance, Downes observed.

Funding

Nearly every panel member discussed some aspect of funding, beginning with LeDuc's blunt assessment that support for government and academic research on public health is severely constrained, and will remain so for the foreseeable future. As a result, he said, investments in disease surveillance and detection must deliver the greatest value for money, and existing systems must be subject to ongoing evaluation. LeDuc advocated a "transparent independent investigation" of the federal BioSense (syndromic surveillance) and BioWatch (aerosol detection) programs to determine whether they are truly answering important questions. This would include considering the potential value of other questions and/or systems and their applicability to standard clinical practice, as well as for the detection of extraordinary disease threats. A similar argument was taken up by panelist and speaker Ian Lipkin, director of Columbia University's Greene Infectious Disease Laboratory (see Summary and Assessment and Chapter 3), who noted that thoughtful investments in the surveillance and detection of acute infectious disease may ultimately pay off in addressing chronic disease, in which infections and immunity appear to play a role. Recognizing that funding for surveillance tends to be tied to specific disease threats, LeDuc encouraged the development of systems that can be adapted to a broad range of conditions (e.g., from avian influenza to any infectious respiratory disease).

Layton identified investment in infrastructure as key to improved disease surveillance by DOHMH. "That means people," she explained. "It means field surveillance staff. It means public health nurses. It is physicians, laboratory support, environmental health scientists, veterinarians, and . . . information technology experts to allow us to process information and respond to it. Syndromic surveillance allows me to know what is going on in the city," she continued, "but the ability to do that [results from a] tremendous investment in staff infrastructure." Similarly, Downes noted that "the collection and analysis of surveillance data

is only one part of the challenge of responding to emerging infectious diseases. Epidemiologic and laboratory resources are needed to investigate early warning signals and take actions to interrupt continued disease transmission."

Workforce Issues

Several panelists identified a shrinking public health workforce as a challenge to infectious disease surveillance and detection, due in part to the relatively low salaries of public health professionals. To encourage the kind of interest and commitment necessary to produce the next generation of public health practitioners, Lipkin suggested engaging the media. "The number of kids who are interested in forensics as a result of CSI has gone up dramatically," he noted. "Why not do something similar in public health?" Karesh argued for rewarding researchers who pursue the public good as their primary goal; for example, those who release key information prior to publication, and those whose negative results are difficult to publish, despite their epidemiological value.

COORDINATION OF DISEASE SURVEILLANCE, DETECTION, DIAGNOSTICS, AND REPORTING

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Most of the presentations at this forum have focused on the technical aspects of surveillance, diagnostics, and detection. My presentation will focus primarily on the challenges of coordination as a leadership responsibility and management imperative, with coordination defined from a business perspective: "Synchronization and integration of activities, responsibilities, and command and control structures to ensure that the resources are used most efficiently in pursuit of the specified objectives" (BusinessDictionary, 2007). Before I address these broad issues, however, I would like to introduce five technical impediments to the coordination of infectious disease surveillance across animal and public health.

Technical Impediments to Coordination

First, there is the challenge of incorporating surveillance into the information architecture of medical and veterinary medical business systems. Medical and veterinary facilities decide to implement information systems when the benefits outweigh the cost of installation and support. Most medical records systems are designed to collect and compile records to enhance business efficiency, an obvious benefit that reduces the volume of paper records and the personnel needed to

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compile the records. Generating bills and tracking cost center performance present different information management challenges than analyzing agent, host, and environment data to support surveillance systems and epidemiological analyses. Although the benefits of having a national or global surveillance system may be readily apparent on a societal level, there may not be a visible return on the investment required for an individual business to participate. Surveillance and epidemiology generally are viewed as public goods, that is, the benefits accrue to the whole society. Hence individual institutions and businesses often are reluctant to participate in national surveillance programs without some inducement such as government grants or preferred insurance rates, or some penalty, like a legal requirement for involvement. Understanding the "value proposition" is critical to forming productive collaborations.

A second challenge involves the lack of a common lexicon, so that certain terms have different meanings in different disciplines. Various ontologies exist to annotate biological terms such as the International Classification of Diseases (ICD) and Standardized Nomenclature for Medicine (SNOMED) for human medicine, and the Standardized Nomenclature for Veterinary Diagnoses and Operations (SNVDO) and Standardized Nomenclature for Veterinary Medicine (SNOVET) for veterinary medicine. The challenges of defining an integrated human/veterinary system are myriad, such as rectifying hand versus paw versus hoof naming conventions and adding population data—a cow is a member of a herd and a chicken a member of a flock, where the population data represent one element of the diagnosis. Although substantial progress has been made, no global standard has emerged for an ideal medical vocabulary for use in both human and veterinary medicine.

A third issue is the need for standardized communication protocols that enable surveillance, detection, and response systems to share data and results in real time. In this age of high-tech communications and increasing international travel, a classic example of the lack of standardization exists with the differences in cell phone or videotaping protocols between the United States and Europe. Agreeing on a standardized approach can be a monumental undertaking, such as establishing an animal identification system in the United States. The U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) worked for years with a variety of stakeholders to reach a decision to move ahead with a 15-character animal identification number, a 13-character group/lot identification number, and a 7-character premises identification number (USDA, 2006).

A fourth concern is how to secure the resources to support surveillance, particularly global surveillance. Despite widespread recognition of the importance of global surveillance for the public good, health-care systems are nationally based and, in a number of countries, funded largely by third-party payers and user fees. The development of the Global Early Warning Systems (GLEWS) in 2006 represents the first joint early warning and response system combining

and coordinating the separate surveillance activities of the World Organization for Animal Health (OIE[2]), the Food and Agricultural Organization of the United Nations (FAO), and the World Health Organization (WHO) (WHO, 2006). However, the GLEWS coverage is variable, reflecting huge differences in the capacity of individual countries in terms of their laboratory resources, trained personnel, internal surveillance systems, and reporting capabilities.

Confidentiality provides a final example of the technical challenges for coordination. Even when secure communications can be guaranteed, protecting individual privacy, proprietary business information, and sensitive national security data are topics of intense debate. Strategies like summarizing individual data to produce group statistics may obscure the very trends that are of public health interest. Differing objectives may bring those who provide the data and those who compile and report the data into conflict. Examples include "shunning" of individuals who test positive for a disease despite a low risk of transmission during casual social contact; regulatory action on voluntarily participating farms after detection of an agent of concern; changes in consumer purchasing patterns of finished products based on comparison of contamination rates on raw ingredients before processing; and imposition of trade restrictions following the voluntary reporting of an animal disease agent detection considered to pose only a limited risk to production agriculture, such as detection of a low-pathology strain of avian influenza in wild birds.

Paradigm Impediments to Coordination

Our collective approach to surveillance is framed by the prevailing paradigms of our society. Currently, coordination of disease surveillance, detection, diagnostics, and reporting is stymied by an overriding philosophical framework comprising our public health focus, our definition of health, our perspective on risk, our fascination with disease agents, our propensity to glorify emergency response, and our preoccupation with technology. A series of examples will help to illustrate these challenges:

- Despite the fact that public health surveillance is all about populations, we tend to think in terms of the individual. Individual stories galvanize public action as they personalize stories of illness, pain, and death. Betty Ford's breast cancer and Rock Hudson's AIDS diagnosis are often cited as turning points for U.S. public health policy for these diseases. Furthermore, our focus tends to be parochial, evaluating public health priorities from our personal and local perspectives rather than considering the world at large.
- We tend to define health as absence of disease; success as complete cure or eradication of an infectious disease scourge; the primary public health function

[2]Office International des Epizooties.

as rapid response to crises; and our compelling public health vision as zero risk. In stark contrast, physicians explain that we can achieve a high quality of life despite a number of illnesses and afflictions; economists argue that the focus on eradication of disease is not optimal use of our health-care dollars; decreasing prevention budgets contribute to the occurrence of crises needing rapid response; and scientists point out that zero risk is unachievable.

- All too often we focus our infectious disease resources on the agent, ignoring the web of causation, including genetics, host immunity, and social and environmental factors. By focusing disproportionately on the agent, we fail to adequately track host and environmental risk factors that contribute to the emergence and reemergence of infectious diseases and we are lulled into the erroneous conclusion that successful risk management depends on identification of the specific agent. However, agent identification was not a prerequisite for the public health heroes who made important contributions prior to the formulation of the germ theory of disease, such as Ignaz Semmelweis (whose advocacy of hand washing drastically reduced mortality due to puerperal fever) and John Snow (a father of epidemiology, who gathered evidence that linked the spread of cholera with water contaminated by waste from infected people).
- We are strongly influenced by what I call the "John Wayne mentality," which dictates that when something goes wrong, someone is to blame and that party must be hunted down and punished and thereby, the problem is solved (often this mindset results in a case of shooting the messenger). We wholeheartedly embrace the war metaphor, wherein public health wages battles against infectious diseases. Such conflicts have winners and losers, and it is our job to win; indeed, victory over infectious disease was prematurely declared by U.S. Surgeon General William H. Stewart in 1967 (IOM, 2006, particularly pp. 1-2).
- We are fascinated by technology. Even though few of us use even a fraction of the power of our computers or cell phones, we rush to upgrade to the latest and greatest improvement of speed, graphics, communications, and games software. While partially inured to the exaggerated claims of biotechnology, genomes, and pharmaceuticals, we still cling to the hope that technology will provide the silver bullet. When we complete careful reviews of our public health program failures, technology is rarely the culprit. The lack of people skills—including leadership and teamwork—is far more commonly cited as a major contributor to public health program underperformance than a shortage of technology. Disciplinary silos and professional egos are more damaging than absence of the latest "techno-solution" or "miracle-mycin."

Coordination as a Leadership and Management Imperative

The overall high health status of people and animals in the United States contributes to the prevailing attitude of "if it ain't broke, don't fix it." Our comparative good health also leads us to focus on the "disease du jour" or the crisis

of the moment rather than prioritizing our investments by the potential impact they can make on measures of population health such as infant mortality, risk factor avoidance, or adolescent pregnancy. In the absence of a headline-grabbing outbreak or the untimely demise of a celebrity, we are loath to fund surveillance systems that could anticipate such threats and trigger proactive prevention campaigns. Success in a disease control program often is met with reduced funding or elimination of the surveillance and disease detection programs on which the success was based. As an example, the successful U.S. campaigns against the zoonoses bovine brucellosis (undulant fever in humans) and bovine tuberculosis (one form of tuberculosis in humans) depended on a traceability system that allowed affected cattle detected at slaughter to be traced back to their herd of origin. Given the eradication successes, however, funding was dropped for the identification systems and the United States has slipped backward in its ability to trace cattle back to the farm of origin. While the most highly trained fire-fighting unit in most communities—that of its local airport—is rarely used, our tendency is to decommission surveillance, detection, diagnostic, and reporting infrastructures when the disease of concern becomes rare.

An Alternative World View

Coordinating surveillance requires that we "begin with the end in mind," as Stephen Covey memorialized (Covey, 1989). What is the surveillance intended to accomplish? Why is coordination important? How will the surveillance results be used? What benefits will the surveillance yield for those who are expected to participate? Presumably the overarching goal of coordinated surveillance is improvement of public health, that is, the health of the community. Public health involves identifying problems, setting priorities, formulating policies to address these priorities, promoting health and preventing illness, and providing access to health care.

Achieving these lofty public health goals requires a very different paradigm characterized by a global perspective, a focus on health, an ecosystem approach (agent, host, environment), a risk management goal, prioritization based on importance rather than urgency, and a commitment to working with people to manage the dilemmas rather than seeking a technology quick fix (Table 4-1).

We increasingly recognize that we live in a complex world of microbial ecology, a world in which microbes are ubiquitous and adaptive and in which disease and emergent disease is the norm rather than the exception. If we think of surveillance only in terms of agent detection, we will not be able to effectively manage these new risks. For example, initial responses to recent foodborne disease outbreaks in leafy greens demonstrated a lack of understanding of complex food production and distribution systems. These complex systems must incorporate multiple critical control points including the application of best practices and targeted monitoring and feedback loops.

TABLE 4-1 Current Public Health Paradigm and Alternative World View

Current Paradigm	Alternative World View
Health is absence of disease	Health is well-being (in mind, body, spirit)
Infectious disease is all about the agent	Infectious disease emerges at the convergence of agent, host, environment
Zero risk is achievable	Zero risk is unachievable; risk management is the goal
Success is eradication/cure	Success is homeostasis with microbes that are ubiquitous, constantly evolving and adapting
Public health function is to react	Public health function is health promotion
Reaction requires agent detection	Risk management can be successful whether or not microbe is identified
Urgency dictates priority	Surveillance informs policy and guides action on basis of importance
Answers lie solely in technology	Answers involve people, politics, partners

SOURCE: Hueston (2006).

Real-time surveillance of food products and their raw materials must be combined with quality control and food safety systems in processing and distribution, sensitive public health disease detection, prompt reporting, and rapid outbreak investigation. The entire food system must retain the flexibility to adjust its risk management strategies to changing risk factors (hosts, agents, and the environment) without waiting for outbreaks to occur. Without a dynamic and adaptive food safety system, significant resources will be squandered on useless activities such as large recalls announced after most of the product has already been consumed.

The Politics of Coordination

Coordination is all about politics, which I define as the interpersonal dynamics that occur whenever two or more people are gathered together. Politics of societies are influenced by culture, and the organizational culture of the various public health agencies and the regulated industries is as germane to the practice of public health as is ethnicity, gender, religion, and other factors. To coordinate—to harmonize in common action and effort—requires effective political processes over the long term. "People skills" are needed to build coordination and collaboration, yet the social sciences are rarely emphasized—or even mentioned—in the

programs that train doctors, public health professionals, veterinarians, and plant pathologists. Interpersonal and teamwork skills are described as "non-technical" or "soft skills" and omitted from the curriculum. As has been demonstrated time and time again, university faculties assume that students "ought to know all that stuff before they get into graduate school or professional school."

Toward Optimal Surveillance

The optimal surveillance system is integrated and dynamic, with ongoing data collection. Real-time analysis would generate information relevant to risk management that would in turn drive policy and action. This ideal surveillance system incorporates feedback processes, permitting continuous, evolutionary change. It would integrate information on infectious disease in humans, domestic animals, wildlife, and plants collected and maintained through cross-disciplinary collaboration such as plant pathologists working in public health or psychiatrists working in veterinary medicine.

What is the way forward toward such a "system of systems?" Beginning with the end in mind, we need to prioritize public health goals. We need to complement agent surveillance with host and environmental monitoring. We need to recognize that societal stability and economic security are critical for maintaining a functional public health infrastructure, and find ways to make "doing the right thing" both beneficial to society and profitable for the private sector. We need multiple functional models that will work in the developing world as well as in industrialized countries. The information systems we need to develop would support global public health. Finally, because we can anticipate many future challenges, we must incorporate capacity for adaptation into the design of integrated surveillance systems.

Changing the Prevailing Paradigms

There is no magic formula for changing paradigms. However, change can occur incrementally, by rewarding progress no matter how slow, and then identifying, documenting, and celebrating successes, large and small. Fostering paradigm change is difficult, requiring a number of simultaneous activities, including:

- We must nurture a new generation of public health professionals who adopt a holistic, global perspective of health, and who look for creative ways to manage risks. We need to imbue these emerging public health professionals with a commitment to transdisciplinary approaches. We also need to encourage them to embrace change and be adaptable in a world that will never be risk free.
- Combining experiential learning opportunities with more didactic educational approaches will enable our new public health professionals to be more

effective, to be more adaptive, to understand complex challenges and opportunities, and to manage the complex dilemmas of the future.

- We must establish a robust, global public health infrastructure that incorporates interoperable high- and low-tech solutions, such as the cell phone surveillance system described in this report (see Johnson and Blazes in Chapter 2). Like Voxiva, we need to bring cultural anthropologists into health delivery teams to examine motivators for promoting public health in different cultures.
- We must examine the ethics of surveillance, and in particular the question as to whether effectively contained disease outbreaks need be reported to the public. I found the HealthMap presentation (see Brownstein in Chapter 2) both exciting and frightening, because it labels countries as to whether or not they have a given infectious disease within their borders. Although that knowledge may help us to detect global disease patterns and target intervention resources, it also has the potential to set back international development, given that reports of infectious disease can lead to trade embargoes and reductions in tourism and investment. This, in turn, will decrease infectious disease reporting. Futhermore, labeling an entire country in terms of disease presence or absence acts against the recognizing potential to safely establish free zones or even agricultural enterprises within a country where a specific disease is widespread.
- Finally, we must build public–private partnerships for global health. While public funding will always be constrained by other societal demands, we can identify potential benefits of improving public health in ways that make sense to corporations. The private sector can move much faster and contribute a wider array of resources toward those shared public health goals than the public sector can.

Strengths, Weaknesses, Opportunities, and Threats

SWOT analysis emerged in the 1960s and 1970s as a strategic planning tool used to evaluate the ***S***trengths, ***W***eaknesses, ***O***pportunities, and ***T***hreats of a project or initiative. Looking at current disease surveillance, detection, diagnostics, and reporting systems, we can draw several conclusions from a brief SWOT analysis.

The public health dilemmas of infectious diseases are global, not local. While our local strengths include the vast array of technology and data at our disposal, our principal weakness is the disparate global environment in which we must operate, where countries vary greatly in terms of infrastructure capacity, human and fiscal resources, and commitment to public health. We are also plagued by the disconnect between surveillance and action, which is exacerbated by the misconception of surveillance as a goal, rather than as a means to an end.

Progress toward integrated, global surveillance is threatened by the potential for unintended consequences. The potential for surveillance to deepen the first-world/third-world divide is a huge threat to global coordination and collaboration. Thus we need to discuss the possible consequences—both intended and

unintended—with our stakeholders and the beneficiaries we serve, both domestically and globally.

A key opportunity lies in the possibility of developing an overarching, integrated, global surveillance plan that will take us out of our disciplinary silos—a plan that sets priorities based on global considerations of public health impacts and identifies the resources necessary for coordination. These priorities necessarily must balance the potential impact on and the degree of buy-in from the community that they are meant to serve. Experience has taught me that ideal solutions lacking community support will fail, while popular, partial solutions will succeed. We must be willing to address today's complex public health dilemmas one small step at a time. After all, as I am frequently reminded by a mentor, "slow progress is progress."

Finally, we have a tremendous opportunity to foster a new generation of global public health leaders who will catalyze coordination through very different paradigms than those held today. Progress toward coordinated surveillance will be accelerated by active transdisciplinary leadership development programs in global public health.

Defining Success

How can we measure our progress toward global coordination of infectious disease surveillance, detection, diagnostics, and reporting? A successful system will allow us to more effectively anticipate new threats and will adapt fluidly to manage risk under novel conditions. It will encourage the formation of public–private partnerships to support surveillance. New leaders will step forward to promote international collaboration toward shared goals. Finally, we will know we have succeeded when we can document incremental improvement in global public health.

IMPROVING INFECTIOUS DISEASE SURVEILLANCE AND DETECTION: A PUBLIC HEALTH LABORATORY PERSPECTIVE

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The practice of infectious disease surveillance has co-evolved with the public health laboratory to address important health concerns with ever-advancing technologies. This ongoing partnership is essential to the continued improvement of surveillance systems. Public health laboratories in the United States are major contributors of infectious disease reports. In Michigan, for example, 60 percent of all laboratory results in the Michigan Disease Surveillance System are received

[3]Laboratory Director.

from the state's public health laboratory. Nationally, public health laboratories perform more than 40 million tests annually and are responsible for generating 35 to 65 percent of all positive laboratory findings for reportable diseases (APHL, 2002).

This essay examines key opportunities for improving infectious disease surveillance from the perspective of the public health laboratory. These include the creation and strengthening of laboratory networks; the acknowledgment and removal of barriers to disease reporting by laboratories; the adoption and adaptation of information technologies by and for laboratory use; and the extension of the laboratory–surveillance partnership to refine and validate syndromic surveillance and rapid field diagnosis of reportable diseases.

Establishing Laboratory Networks

Surveillance benefits from the collection of comprehensive data from diverse sources, and public health laboratories can play an instrumental role in facilitating and garnering support for this process. The public health laboratory community increasingly has embraced the concept of laboratory networks that enable a wide variety of laboratories to contribute their testing results to surveillance and disease control databases. Examples of current and potential laboratory networks are described in the following paragraphs.

The National Laboratory System

In 2001, the Centers for Disease Control and Prevention (CDC) launched pilot programs in four states (Michigan, Minnesota, Nebraska, and Washington) to implement a National Laboratory System (NLS) of statewide laboratory networks (CDC, 2004). Since the initiation of the NLS, many public health laboratories have undertaken network development programs within their states that improve public health response and surveillance through partnerships with traditional and nontraditional partners, including clinical and hospital laboratories, health advocacy organizations, agriculture and veterinary laboratories, and commercial laboratories.

Integrated Surveillance Networks

The public health laboratory is the juncture at which medical laboratory science and public health surveillance intersect. Due to this unique position, the public health laboratory must provide the leadership to forge relationships that eventually will lead to the integration of nontraditional laboratory surveillance data sources into public health surveillance.

Recent infectious disease emergence and foodborne disease outbreaks demonstrate the need for public health surveillance to integrate nontraditional sources

of data. Peanut butter, fresh spinach, and tomatoes recently have been identified as vehicles of enteric bacterial infections. In these examples, improved access to, and monitoring of, agriculture and food processor laboratory results by public health practitioners may have enabled earlier identification of disease activity and outbreaks. Because most emerging infectious diseases are zoonotic, animal diagnostic testing is clearly another rich source of data to collect for improved surveillance of emerging, reemerging, or novel infections.

Technical and Professional Networks

Although network-building activities rarely involve increased screening or testing for public health laboratories themselves, public health laboratories undertaking these efforts frequently provide technical training (e.g., in rapid screening for bioterrorism agents), consultation (e.g., on antimicrobial resistance testing), and feedback (e.g., the use of laboratory reports for surveillance and outbreak response). Network development also encourages the development of best practice guidelines for tests of public health importance (e.g., rapid HIV testing, estimated glomerular filtration rate, cholesterol screening). Even simple efforts such as the development of educational materials or tools and presentations to remind laboratorians about the importance of their role in disease reporting, or the participation of public health laboratories in state and regional clinical laboratory professional organizations, can ultimately improve the completeness and timeliness of disease reporting. Equally important, technical and professional networks develop relationships among organizations that can work together to refine surveillance systems through the use of mechanisms such as electronic medical record exchanges and electronic laboratory reporting.

Addressing Barriers to Reporting

To improve the timeliness and completeness of reporting by laboratories, and thereby the quality of surveillance, the following critical barriers must be addressed.

Reporting Costs

The cost of preparing and shipping isolates and specimens to public health laboratories for reference and molecular epidemiology testing are not reimbursed by third-party insurance providers or public health agencies. Recent changes to the U.S. Postal Service (USPS) regulations prohibiting the use of the USPS for shipping infectious agents have only exacerbated this problem. For example, some states require that clinical laboratories submit their public health laboratory isolates of *Mycobacterium tuberculosis* and other microbes. These isolates must now be shipped to public health laboratories by commercial courier services that

attach a $50 surcharge to each infectious agent shipment. The burden of this cost is borne by the clinical or other originating laboratory and is not reimbursable by public or third-party insurers.

Shrinking Workforce

The medical laboratory is beginning to see the first signs of a looming shortage of trained professionals. Between 1980 and 2003, the number of medical technology programs declined from nearly 800 to 240, and the annual number of graduates of accredited programs declined from 6,184 to 1,668 (Personal communication, S. Anderson at the 2004 Clinical Laboratory Education Conference). The laboratory professional workforce will be exacerbated as the majority of the workforce reach retirement age in the next two decades. Less than 10 percent of the laboratory professional workforce is eligible for retirement now, but in the next 10 years, approximately 40 percent of the current workforce will be eligible, and in 15 years 62 percent will be eligible (Personal communication, S. Anderson at the 2004 Clinical Laboratory Education Conference). Vacancies due to an inadequate pool of qualified candidates translate into less time available to prepare and ship isolates and specimens to public health laboratories, prepare and submit reports of reportable diseases to public health agencies, and participate in training on emerging health issues and disease reporting.

Labor-Intensive Methods

Antigen detection and other simple point-of-care tests, among other emerging testing technologies, may be more rapid and require less equipment and labor. However, public health reference and molecular testing used to detect and investigate disease outbreaks often requires a microbial isolate. For example, isolates of suspect *Mycobacterium tuberculosis* must be available for public health testing using currently practiced methods for the public health testing of reference level identification (Metchock et al., 1999), antimicrobial susceptibility testing (NCCLS, 2003; Plikaytis, 1992), and genotyping (Cowan et al., 2002). Public health laboratories may need to perform more preliminary testing to obtain isolates from rapid test specimens and work with front-line practitioners to assure quality of point-of-care tests and collection of additional specimens for confirmatory and molecular epidemiology testing. Eventually, alternative public health laboratory confirmatory and typing methods that do not require microbial isolates will need to be developed.

Standardized Reporting

Laboratory testing to identify potential cases of reportable disease is increasingly performed for multiple states by commercial clinical laboratories. Com-

municable disease reporting requirements, however, vary from state to state. Reporting and isolate submission compliance by multistate laboratories will only improve when states standardize reporting and isolate submission lists and formats.

Adoption and Adaptation of Information Technology

Information technology that can improve current surveillance systems is available, but it has not been universally adopted. CDC's Public Health Information Network (PHIN)[4] standards make adopting this technology nationally feasible. As with the establishment of laboratory networks, trust and resources are needed to achieve data exchange between the clinical laboratory and public health surveillance systems in the following critical areas.

Electronic Laboratory Information System Reporting

As noted in the contribution by Joseph Lombardo (see Chapter 1), many hospitals use the Health Level Seven (HL-7) format, which can create a message from the originating laboratory information system and transfer it to a surveillance information system that captures and stores disease surveillance data for case investigation and data analysis. Widespread adoption of electronic laboratory reporting would eliminate the current slow, labor-intensive practice of transcription of results from a laboratory information system to a paper form and submission by mail or reentering results to a web-based interface with the surveillance system. Broader adoption of this faster and more complete method of laboratory reporting may require additional linkage to hospital information systems that contain patient-specific information not available in the laboratory information system. Also, resource commitment is required from both the clinical laboratory and the surveillance system to initiate and maintain electronic laboratory reporting.

Electronic Health Records

Regional initiatives are underway to develop electronic health record exchanges throughout the United States. While economics and quality of care are often the motivating forces in the development of the health information exchange networks, these networks can and should be designed and used for public health surveillance (and registry) reporting. Public health entities are able to

[4]The PHIN is CDC's vision for advancing fully capable and interoperable information systems in the many organizations that participate in public health. PHIN is a national initiative to implement a multiorganizational business and technical architecture for public health information systems (CDC, 2007).

receive patient-specific health information while still complying with the Health Insurance Portability and Accountability Act (HIPAA).[5]

The Role of the Laboratory in Syndromic Surveillance and Field Diagnosis

Syndromic Surveillance

Novel surveillance systems are being piloted and used in a variety of settings for a variety of uses. Laboratory-based reporting is highly specific but not sensitive; conversely, syndromic surveillance is very sensitive, but not specific. Syndromic surveillance systems are designed to detect large-scale events clustered in time and space. They will not detect low-frequency events like the first cases of disease outbreak.

Syndromic surveillance systems can complement, but cannot replace, traditional case and laboratory-based reporting systems. Syndromic surveillance system data should be validated periodically with traditional case confirmation and laboratory testing methods. It is also important to evaluate programmatic investments in syndromic surveillance early warning systems, such as BioSense and BioWatch, to determine if they have been used as intended and if the investment is warranted (GAO, 2005).

Field Diagnosis

Global public health surveillance and clinical patient care may benefit from easily performed microbe-specific rugged tests. The "gold standard" tests are essentially unavailable in many parts of the world and are often so time consuming that they stymie disease control efforts. Exciting advances in the development of field-ready diagnostics are resulting from public–private partnerships. However, investment in such technology should not supersede investments or precede efforts in total quality systems.

A comprehensive laboratory quality system approach is relevant for any test, whether it is complex or simple to perform, and in any testing setting, whether it is the traditional laboratory, the clinic, or the field (CLSI, 2004). Inaccurate results generated from unmonitored testing can lead to misdirected patient care, inaccurate disease reporting to surveillance systems, and wasted resources. When rugged, simple field tests are used, traditional microbiology also should be accessible to provide reference-level testing to detect emerging infectious diseases (i.e., microbes that will not be recognized by disease-specific tests) and to validate field tests on an ongoing basis.

[5]Enacted in 1996, HIPAA required the Department of Health and Human Services to establish national standards for electronic health-care transactions and national identifiers for providers, health plans, and employers. It also addressed the security and privacy of health data (HHS, 2005).

Conclusion

As investments are made in surveillance systems, it is also critical to commit adequate resources to analyzing and responding to the increased volume of surveillance data. For example, PulseNet[6]—a much-heralded early warning system for foodborne diseases—does not live up to its full potential due to inadequate resources for laboratory studies and epidemiology. Moreover, the collection and analysis of surveillance data is only one part of the challenge of responding to emerging infectious diseases. Epidemiologic and laboratory resources are needed to investigate early warning signals and to take effective actions to break the cycle of disease transmission.

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[6]PulseNet is a national network of public health and food regulatory agency laboratories coordinated by the CDC. The network consists of state health departments, local health departments, and federal agencies (CDC, U.S. Department of Agriculture/Food Safety and Inspection Service, Food and Drug Administration). PulseNet participants perform standardized molecular subtyping (or "fingerprinting") of foodborne disease-causing bacteria by pulsed-field gel electrophoresis (PFGE) in order to distinguish strains at the DNA level. DNA "fingerprints," or patterns, are submitted electronically to a dynamic database at CDC, allowing for rapid comparison of the patterns (CDC, 2006).

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