

Public Health Informatics: Improving and Transforming Public Health in the Information Age

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Development of effective public health information systems requires understanding public health informatics (PHI), the systematic application of information and computer science and technology to public health practice, research, and learning. PHI is distinguished from other informatics specialties by its focus on prevention in populations, use of a wide range of interventions to achieve its goals, and the constraints of operating in a governmental context. The current need for PHI arises from dramatic improvements in information technology, new pressures on the public health system, and changes in medical care delivery. Application of PHI principles provides unprecedented opportunities to build healthier communities.

Key words: *computers, communications, informatics, education, information systems, information technology, public health, software*

J Public Health Management Practice, 2000, 6(6), 67–75
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Introduction

Effective public health practice requires timely, accurate, and authoritative information from a wide variety of sources.¹ Not surprisingly, public health professionals have been among the earliest adopters of computers and other information technologies, and numerous individually useful computerized information and surveillance systems have been developed.^{2,3} Nevertheless, we need to utilize a more systematic and informed approach to the application of information science and technology in order to take full advantage of its potential to enhance and facilitate public health activities.⁴ This approach is em-

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The authors appreciate the helpful comments and suggestions from Edward L. Baker, Jr., and Dixie E. Snider, Jr.

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bodied in the principles and practices of a new discipline called *public health informatics*.

What Is Public Health Informatics?

We define public health informatics as *the systematic application of information and computer science and technology to public health practice, research, and learning*.⁵ Public health informatics is primarily an engineering discipline, that is, a practical activity, undergirded by science, oriented to the accomplishment of specific tasks. The scope of public health informatics includes the conceptualization, design, development, deployment, refinement, maintenance, and evaluation of communication, surveillance, and information systems relevant to public health. It requires the application of knowledge from numerous disciplines, particularly information science, computer science, management, organizational theory, psychology, communications, political science, and law. Its practice must also incorporate knowledge from the other fields that contribute to public health (e.g., epidemiology, microbiology, toxicology, statistics, etc.).

Although public health informatics draws from multiple scientific and practice domains, computer science and information science are its primary underlying disciplines. Computer science, the theory and application of automatic data processing machines, includes hardware and software design, algorithm development, computational complexity, networking and telecommunications, pattern recognition, and artificial intelligence. Information science encompasses the analysis of the structure, properties, and organization of information, information storage and retrieval, information system and database architecture and design, library science, project management, and organizational issues such as change management and business process reengineering.

Automation vs. Reengineering

Public health informatics involves more than simply automating existing activities. It enables the redesign of systems using approaches that were previously impractical or not even contemplated. For example, a central registry in Arizona that stores immunization data from public and private providers

throughout the state was recently used to dramatically focus prevention resources by determining geographically where children were at risk of disease due to under-immunization.⁶ Similarly, at a large managed care organization in California, the immunization registry's computerized database allowed the precise identification, recall, and re-vaccination of four children who had received vaccine from a sub-potent lot, avoiding inconvenience and worry for the parents of 15,000 unaffected children who would have been recalled if the information system had not identified those affected, as well as saving an estimated \$100,000 in administrative, labor, and pharmacy costs.⁷

Surveillance is another aspect of public health that could be dramatically transformed by the application of information technology. For example, clinical information systems could be continuously monitored for changes in the incidence or characteristics of identifiable illnesses or even specific clusters of findings. Such analysis is computationally intensive and has not been possible until recently because the data were not available in electronic form and the number of possible symptom/sign patterns was too large to manage. The capacity to rapidly identify anomalous patterns of illness and injury is important for many reasons, including the early detection of a covert bioterrorist attack.⁸

In the near term, most public health information system projects will focus on improving the efficiency and/or effectiveness of traditional public health practice. Over time, however, the promise and challenge of public health informatics will be in engineering innovative new ways to promote public health using the power of information science and technology.

Principles of Public Health Informatics

Public health informatics is related to medical informatics⁹ in several respects. Both disciplines seek to use information science and technology to improve human health; there are subject matter areas of common concern (e.g., standards for vocabulary and information exchange); and lessons learned in medical informatics often apply to public health informatics. Further, there are applications for which there is no real distinction between public health and medical informatics, such as systems for

accessing public health data from electronic medical record systems or providing patient-specific prevention guidance at the clinical encounter. Nevertheless, we believe that public health informatics is a new and distinct specialty area within the broader discipline of informatics, defined by a specific set of principles and challenges.

Our view is that the various informatics specialty areas (e.g., nursing informatics and medical informatics) are distinguished from one another by the principles underlying their respective application domains (i.e., nursing and medicine), as well as by the differing natures and challenges of their informatics applications. In the case of public health informatics, there are four principles, flowing directly from the scope and nature of public health, that distinguish it from other informatics specialty areas. These four principles define, guide, and provide the context for the types of activities and challenges that comprise this new field:

1. The primary focus of public health informatics should be on applications of information science and technology that promote the *health of populations* as opposed to the health of specific individuals. As a discipline, public health focuses on the health of the population and the community, as opposed to that of the individual patient. In the health care setting, the major unit of attention is an individual with a specific disease or condition. In public health, consideration for the community as the patient may require “treatment” such as quarantine or disclosure of the disease status of an individual to prevent further spread of illness. It also requires attention to environmental factors (e.g., water quality and automotive safety) that affect the health risk of entire populations rather than specifically identifiable individuals.
2. The primary focus of public health informatics should be on applications of information science and technology that *prevent* disease and injury by altering the conditions or the environment that put populations of individuals at risk. Public health emphasizes the prevention of disease and injury versus intervention after the problem has already occurred. Although notable exceptions exist, traditional health care largely treats individuals who present with a disease, while public health seeks to avoid the

conditions that led to the disease in the first place.

3. Public health informatics applications should explore the potential for prevention *at all vulnerable points in the causal chains* leading to disease, injury, or disability; applications should not be restricted to particular social, behavioral, or environmental contexts. In public health, the nature of a given preventive intervention is not predetermined by professional discipline, but rather by the effectiveness, expediency, cost, and social acceptability of intervening at various potentially vulnerable points in a causal chain leading to disease, injury, or disability. Public health interventions have included, for example, legislatively mandated housing and building codes, solid waste disposal and wastewater treatment systems, smoke alarms, fluoridation of municipal water supplies, and removal of lead from gasoline. Contrast this with the modern health care system, which generally accomplishes its mission through clinical and surgical encounters. While some of these encounters can properly be considered public health measures (e.g., vaccination), public health action is not limited to the clinical encounter.
4. As a discipline, public health informatics should reflect the *governmental context* in which public health is practiced. Much of public health operates through government agencies that require direct responsiveness to legislative, regulatory, and policy directives, careful balancing of competing priorities, and open disclosure of all activities. In addition, some public health actions involve authority for specific (sometimes coercive) measures to protect the community in an emergency. Examples include medication or food recalls, closing down a restaurant or contaminated pool or lake, and changes to immunization policy (e.g., the recent change in recommended use of rotavirus vaccine¹⁰).

In addition to these principles, the nature of public health also defines a special set of informatics challenges. For example, to assess a population’s health and risk status, data must be obtained from multiple disparate sources such as hospitals, social service agencies, police, departments of labor and industry, population surveys, on-site inspections, etc. Data

about particular individuals from these various sources must be accurately combined; then individual-level data must be compiled into usable, aggregate forms at the population level. This information must be presented in clear and compelling ways to legislators and other policymakers, scientists, advocacy groups, and the general public, while ensuring that the confidentiality of the health information of specific individuals is not compromised. Together with the principles articulated above, these and other special challenges define public health informatics as a distinct specialty area.

Why Now?

Public health informatics has become critical at this time because of improvements in information technology, new challenges to the public health system, and changes in the medical care delivery system. Today's computer systems are faster and cheaper than ever before, and prices are continuing to decrease rapidly. In fact, computer hardware is no longer the major cost it once was in information system development projects. More importantly, the Internet has emerged as both a universal communications medium and the source of a universal graphical user interface—the World Wide Web—accessed with Internet browser software. This provides a powerful new paradigm for standardized implementation of the communication capabilities that are central to all information systems. A Web browser interface potentially allows universal access without the necessity for development or deployment of specific software or communications protocols for potential users. Updating information systems is greatly simplified since new versions of Web-based applications are immediately available to users with-

out distribution of new software. Most system development is now utilizing this paradigm, with the resultant creation of many new and powerful tools to streamline and simplify the process. As a consequence, information system development is now faster and easier than ever before. In this environment, the benefits of public health information systems are both more obvious and more easily achievable, and thus much more compelling.

Meanwhile, the need for new and improved information systems for public health is growing because of new challenges related to antibiotic-resistance, emerging infections,¹¹ and chemical and biological terrorism,⁸ for which national public health information systems are either inadequate or nonexistent. As a result, there is a growing interest in capturing information electronically from sources outside official public health organizations, such as hospitals, laboratories, poison control centers, and environmental agencies. This monitoring function of public health will be especially crucial in the event of a covert bioterrorist attack. The rapidity with which the event is detected, analyzed, and understood will determine the timeliness and effectiveness of the medical and public health response, and therefore the extent and severity of its impact upon the health and well-being of the affected community. Detection of insidious terrorist attacks will require effective linkage of data from many different sources both within and outside of public health, with rapid dissemination of data to those who need to take action to protect the health of the public. Thus, public health information systems must expand beyond their current vertical, disease-based orientation and develop seamless electronic exchange of all types of data. Efforts must now be concentrated on accessing data from key sources, using standards for data elements and transmission of data, and capturing data that are already available in electronic form, especially from the health care system.

Public health is also changing dramatically as a result of the rapid evolution of the medical system, primarily due to the growth of organized health care delivery models, including health maintenance organizations. By 1997, nearly 70 million Americans were enrolled in health maintenance organizations, a tenfold increase from 1978.¹² This includes mounting numbers of Medicare and Medicaid beneficiaries who are being shifted into managed care to control

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costs and improve access. In addition, membership in preferred provider organizations, another form of managed care, is increasing rapidly. Continuing mergers and acquisitions among hospitals and medical practices along with wider variability in the insurance products offered has also led to fluidity in the size and composition of health-care organizations. These changes provide important opportunities for public health and managed care to collaborate on shared concerns for cost-effective health care, prevention, and population health. For example, some health plans have implemented practices geared toward improving the level of immunization and cancer screening among their enrollees.¹³ Another important factor is the shift of public health from direct delivery of certain health care services toward ensuring (through regulation and/or negotiation) that appropriate health services are available and accessible from other health care providers. Information systems can be the key to facilitating such data-sharing collaborations and assurance activities.

Major Challenges

Although there are numerous ways in which information science and technology can improve public health practice, there are three areas that represent grand challenges for public health informatics: developing coherent, integrated national public health information systems; developing closer integration between public health and clinical care; and addressing pervasive concerns about the impact of information technology on confidentiality and privacy.

One major goal of public health informatics is ensuring the capacity to assess community problems in a comprehensive manner through the development of integrated nationwide public health data systems. This will require a clear definition of public health data needs and the sources for these data, consensus on data and communications standards—to facilitate data quality, comparability and exchange—along with policies to support data sharing and mechanisms and tools for accessing and disseminating data and information in a useful manner. Since electronic reporting will increasingly form the basis for surveillance systems, developmental efforts must also address issues such as unambiguously defining the specific medical conditions that trigger various types of automated data transmissions, working with report-

ing organizations to ensure that they have appropriate software and electronic communications capabilities, and ensuring that there is adequate capacity for analysis of the tremendously increased volumes of public health data that are anticipated.

Agreement on standards is particularly challenging because of the diverse needs of the many groups who record and use health information, including providers, payers, administrators, researchers, and public health officials. Most of the coding systems and standards currently in use have not previously taken into account public health data needs, and public health's interests are not uniformly regarded as consistent with the business needs of other organizations.¹⁴ However, the Health Insurance Portability and Accountability Act of 1996 (HIPAA) mandates that the Department of Health and Human Services adopt data standards for the electronic transmission of administrative and financial data related to health care (see <http://aspe.os.dhhs.gov/admsimp>). This legislation has provided the impetus for various standards-development organizations and terminology groups to work collaboratively to harmonize their separate systems. Recognizing the importance of standards, several programs at the Centers for Disease Control and Prevention (CDC) are actively involved with the established standards development organizations (SDOs), e.g., HL7. For example, the National Center for Injury Prevention and Control is coordinating a national effort to develop uniform specifications for data entered in emergency department patient records.¹⁵ In addition, CDC has embarked on several agency-wide standards-related activities through its Health Information and Surveillance Systems Board (HISSB), including proposing standards for data elements important to public health and ensuring that the views of all our public health partners are represented at the SDOs (see <http://www.cdc.gov/od/hissb>).

A second major challenge for public health informatics is facilitating the improved exchange of information between public health and clinical care. Many of the data in public health information systems still come from forms filled out by hand, which are later computer-coded. Even where reporting is electronic, initial data entry is typically still manual. This results in serious underreporting of many reportable diseases and conditions.¹⁶ Data need to flow automatically to public health from clinical and

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laboratory information systems. When these data are appropriately compiled by public health information systems, they should allow more rapid and accurate assessments and disease control responses, as well as the formulation of improved clinical guidelines and interventions. Conversely, automated presentation to clinicians of prevention guidelines has been shown to improve clinical care,¹⁷ and there are numerous other ways in which the skills and activities of the public health community (e.g., community outreach) could work to the benefit of clinical care. Electronic information sharing and data exchange provide the means by which we can better integrate public health and clinical care activities, but a great deal of creativity and hard work are needed to take full advantage of these opportunities.

Finally, privacy, confidentiality, and security are pervasive and persistent challenges to progress in public health informatics. Information systems are correctly perceived by the public to be a double-edged sword—whatever is done to make integrated, comprehensive information more easily available for laudable and worthwhile purposes must of necessity create new opportunities for misuse. Public health often collects extremely sensitive personal medical information that has the potential for tremendous harm if improperly disclosed. Federal legislation that provides a fair and workable balance between individual privacy and the common good is needed to both reassure the public and establish legal guidelines for handling sensitive information. While HIPAA will provide confidentiality standards for all health plans (including Medicare and Medicaid), clearinghouses, and providers who use electronic

data, public health agencies need to adopt and enforce confidentiality policies that incorporate fair information practices¹⁸ and utilize state-of-the-art security measures to implement those policies. While public health has had an excellent record of information protection in the past, recent inappropriate releases of information and the lack of uniformly stringent policies across the nation are cause for concern.¹⁹ To ensure successful information system development, public health informatics practitioners must therefore be fully cognizant of these issues and prepared with methodologies and technologies for addressing them, e.g., effective de-identification of data at the earliest opportunity in the aggregation process.

Next Steps

Recognition of the need for public health informatics

The field of informatics is unfamiliar to most public health professionals. In consequence, public health leaders and others responsible for information systems and technology decisions are often not fully cognizant of the basic sciences of this discipline and the accumulated experience available. Without such awareness, the public health community has only recently begun to appreciate (for example) the need for both data standards and comprehensive information architecture for public health. This has contributed to the development of the current patchwork quilt of incompatible or nonintegrated surveillance and data systems found in public health agencies at every level.

The rapid evolution and widespread dissemination of general-purpose data management software and categorically focused public health surveillance and information systems have resulted in substantial exposure to the benefits of information technology without a complete appreciation of the underlying principles and practices required to successfully develop comprehensive integrated data systems that bridge programmatic boundaries. The ease of creating small, single-purpose systems tends to mask the inherent complexities of large-scale information system development, such as the need for well-informed planning and broad consensus. One of the main tasks of leaders in public health informatics is

coordination and consensus-building regarding the types of systems that should be developed and how they will operate.

Training

Since information technology (IT) is now a critical part of the armamentarium of public health, some level of informatics training for both new and existing practitioners is essential. Just as every public health worker needs a basic knowledge of epidemiology, a basic understanding of public health informatics is now a necessity for effective practice in the information age. A deeper level of informatics training is needed by public health leaders and managers to successfully tackle their decision-making and management responsibilities with regard to information systems development projects. Hopefully, such understanding will improve reported systems development failure rates currently in the 30 percent range.^{20,21} Finally, a cadre of public health informaticians with comprehensive training and experience in both public health and informatics is needed to serve in leadership, research and teaching roles, such as chief information officers for state public health agencies and informatics faculty at schools of public health.

The competencies and knowledge needed by a public health informatician include an understanding of the respective roles and domains of IT and public health team members; the ability to develop and use an IT architecture; a working knowledge of information system development, networking, and database design; familiarity with data standards; a clear understanding of privacy and confidentiality issues, as well as security technologies; and skills in IT planning and procurement, IT leadership, managing change, communication, and systems evaluation research. Curricula are needed for developing these competencies at a basic level for the entire public health work force, an intermediate level for public health managers and leaders, and an advanced level for public health informatics specialists and researchers. CDC has made some initial efforts to develop the needed educational programs through the public health informatics fellowship (see <http://www.cdc.gov/epo/dphsi/informat.htm>), the public health informatics course,²² and a cooperative effort

with the National Library of Medicine to help train public health workers in the effective use of the information resources available on the Internet. Eleven public health graduate programs in the United States already offer an informatics course, while an additional 13 are planning to do so within the next two years,²³ and cooperative efforts are underway to define informatics performance standards as part of the National Public Health Performance Standards Program.²⁴ These and other efforts should continue and be expanded to address the public health informatics training needs of the current and future public health work force.

Physical infrastructure/architecture

A prerequisite to the widespread use of powerful new information applications is the pervasive deployment throughout the public health system of modern computers that are interconnected through a standards-based network. In recent years, substantial progress has been made toward this goal. Beginning with the Information Network for Public Health Officials (INPHO)²⁵ and continuing with the Health Alert Network²⁶ component of the bioterrorism preparedness initiative, CDC has made systematic efforts to improve the nation's public health telecommunications, information, and distance-learning infrastructure by promoting Internet connectivity and other information infrastructure for state and local public health workers. Several other federal agencies (e.g., the National Library of Medicine) have also provided funds to promote Internet connectivity and use, and many state and local health departments have invested substantial resources of their own in computing and network technology. In the private sector, the Robert Wood Johnson Foundation has awarded more than \$20 million to develop immunization tracking systems, and others have joined this effort, including the Annie E. Casey, Wellness, Skillman, Flinn, and David and Lucile Packard foundations.²⁷ Although less than half of all public health workers currently have Internet-connected computers on their desks,²⁸ recent progress has been remarkable. Just five years ago, for example, the computing and networking environment was such that most state and local public health professionals had never used e-mail. Today in many states, e-mail has become an indispensable communications tool used for every aspect of public

health. We need to continue and expand our efforts until the entire public health system has a modern information, communications, and distance-learning infrastructure supporting all critical public health data and information systems.



The confluence of improved information systems and technologies, new challenges to the public health system, and changes in the medical care system presents a unique opportunity, to not only improve the efficiency and effectiveness of public health practice, but to transform fundamentally some aspects of public health practice itself. We believe the new and evolving discipline of public health informatics is the key to systematically and scientifically exploiting this opportunity to the benefit of the public's health.

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