Chapter 5
Public Health Informatics Infrastructure

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Abstract To monitor and protect communities, societies create public health infrastructures. A capable, prepared public health infrastructure possesses a skilled public health workforce, robust information and communications technologies (ICT), and effective organizations. Yet there are numerous challenges facing public health agencies that seek to update and evolve the public health infrastructure, including budget constraints, rapidly changing ICT, and increased demands on public health workers. To meet the challenges facing public health, organizations must implement a technical architecture that enables integration across information siloes in public health. Organizations must also redesign work processes and system interfaces to support changing work patterns in public health. Finally, public health informaticians must emerge as leaders who can build and support the evolving public health infrastructure. This chapter defines the public health infrastructure, the challenges facing its implementation, and the core components that will help drive public health organizations to meet current and future information needs.

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Learning Objectives

1. List and describe the three components of the public health infrastructure.
2. List and describe four dimensions of health care data.
3. List and describe seven components of a health information infrastructure.
4. Discuss twenty-first century policies affecting the collection, management, and use of patient data effecting public health organizations and functions.
5. Define the role of a public health informatician.
6. Identify the challenges facing integration of health data across multiple information systems such as electronic health records.

Overview

To monitor and protect communities, societies create public health infrastructures. A capable, prepared public health infrastructure possesses a skilled public health workforce, robust information and communications technologies (ICT), and effective organizations. Yet there are numerous challenges facing public health agencies that seek to update and evolve the public health infrastructure, including budget constraints, rapidly changing ICT, and increased demands on public health workers. To meet the challenges facing public health, organizations must implement a technical architecture that enables integration across information siloes in public health. Organizations must also redesign work processes and system interfaces to support changing work patterns in public health. Finally, public health informaticians must emerge as leaders who can build and support the evolving public health infrastructure. This chapter defines the public health infrastructure, the challenges facing its implementation, and the core components that will help drive public health organizations to meet current and future information needs.

Introduction

Every nation, state, and local community faces threats to its health from disease, environmental, and human (e.g., war, bioterrorism) agents. To monitor and protect the community, societies create public health infrastructures. A public health infrastructure can be envisioned as a framework composed of three interconnected *systems*:

1. *Organizations* – Governmental and non-governmental entities with interrelationships that create and enforce policies to protect, monitor, and improve population health.
2. *Information and communications technologies (ICT)* – Hardware, software, and devices that capture, store, manage, exchange, and create data and information used by public health organizations and its workforce.
3. *People* – The public health workforce, which contains both personal and professional interrelationships within and between organizations.

A capable, prepared public health infrastructure possesses a skilled public health workforce, robust ICT, and effective organizations [1]. Since the start of the twenty-first century, the need for an improved public health infrastructure has been a recurring theme in reports at local, state, and national levels around the world. These reports highlight that the existing infrastructure for public health is underprepared for events like the September 11, 2001 and subsequent anthrax attacks in the United States [2–4].

Following events in the early twenty-first century, public health invested heavily to increase its capacity for syndromic surveillance, or the detection of initial manifestations of disease before diagnoses are established [5–7]. This capacity is crucial for national security, and use at the 2002 Winter Olympics, the Indianapolis 500, and other high profile events showed that a contemporary public health infrastructure can provide effective surveillance [8, 9]. While funding for preparedness has been important for updating the public health infrastructure, the focus on syndromic surveillance has diverted attention away from other areas of population health, including communicable diseases as well as the rising epidemic of chronic illness [10]. Going forward, public health agencies are challenged to develop infrastructures that are flexible, with capacity for addressing outbreaks due to terrorism, the food supply chain, migration, and chronic illness. Major shifts in health care financing, the growth of electronic health record (EHR) systems in health care delivery, and a widening array of data sources necessary for population health necessitate further investment in and upgrades to the public health infrastructure.

The Affordable Care Act of 2010 authorized a number of payment reforms to clinical health, including the creation of accountable care organizations in which providers are charged with managing defined populations [11]. Accountable care organizations (ACOs) are further required to conduct community health assessments and report population level metrics to payers, including the US Centers for Medicare and Medicaid Services (CMS). Such changes in the health system challenge traditional roles for public health agencies. Armed with sophisticated electronic information systems, ACOs and payers seek to collect, manage, analyze and report data on chronic diseases, the communities where their populations reside, and the health of their respective populations. Public health agencies must, in turn, evolve from being the only entities capable of assessing and monitoring population health to strategic and enabling partners involved in population health practice.

Health care information management is also experiencing rapid transformation with its shift from paper to electronic records. The adoption and use of information technologies to capture, store and analyze health information began in earnest in the late 1990s. However, the Health Information Technology for Economic and Clinical Health (HITECH) provisions of the American Recovery and Reinvestment Act of 2009 have accelerated adoption by providing incentives to hospitals and physicians to become meaningful users of electronic health record (EHR) systems [12]. To qualify for the incentives, hospitals and providers must comply with a set of administrative rules from CMS [13]. These rules include a set of public health reporting objectives, including the submission of electronic laboratory reports to public health departments for notifiable conditions, submission of information for syndromic surveillance programs, and increased exchange of information with immunization registries. The increasing adoption of EHR systems by hospitals and providers has prompted the Centers for Disease Control and Prevention (CDC), Council of State and Territorial Epidemiologists (CSTE), the Association of State and Territorial Health Officials (ASTHO), and National Association of City and County Health Officials (NACCHO), among others, to urge state and local health departments to prepare for a sharp increase in electronic reporting of data [14, 15].

A sharp increase in electronic reporting of information is ushering in a new era in public health where agencies are increasingly moving from hunter-gatherers of data silos to agrarian cultivators of shared information farms. Historically, public health workers were dispatched into the field to collect data directly from a variety of sources including but not limited to patients, nurses, physicians, allied health professionals. The rise of EHR systems and health information exchange [16] has resulted in more data and information being electronically reported from health care providers to public health agencies. In addition, electronic surveying and crowdsourcing technologies enable public health agencies to capture increasing amounts of information on health behaviors directly from consumers [17]. Current trends suggest that in the future, public health agencies will spend less time gathering the data they need to monitor the health of populations. Public health workers will instead focus their time and energy on analysis and application of the information received. The exploding use of ICT in health care providers and other health-related organizations has also increased the number of potential sources of data for use in public health processes. The shift from hunter-gatherer to data agrarian will also mean that public health agencies will no longer control the entire information chain, becoming collaborators and secondary users of data collected for other, typically clinical, purposes [10, 14].

In this chapter we describe the key elements for a successful, capable public health infrastructure that can address these challenges. We begin by describing core technologies necessary to support existing and evolving needs of public health organizations. Next we discuss the role of public health organizations in designing and managing the public health infrastructure. Finally, we discuss the critical role that people play in supporting and evolving the public health infrastructure.

A Technical Architecture for Public Health

Historically, public health agencies have created and maintained information system silos that served individual divisions aligned with specific business and regulatory processes (e.g., HIV/AIDS, immunization registry, environmental monitoring). Such a model makes it difficult for program areas to share information with one another, and it requires agencies to gather and store the same data in multiple places. Furthermore, multiple silos increase health agency costs for hardware and software licenses, as well as for personnel costs required to manage multiple systems. Given a changing ICT landscape in which data is cheap, an increasingly ubiquitous cloud for processing and storage, and agencies' need to integrate data and information from a growing list of electronic sources, thought leaders in public health informatics now recommend a standardized approach to collecting data once and using it for multiple business processes within a public health organizations [10, 18]. So called *Write Once, Read Many (WORM) strategies* require that data be normalized – or standardized – to enable each application or data user to share the same understanding of what the data and information mean.

The technical infrastructure in public health, depicted in Fig. 5.1, must seek to normalize data and information across four fundamental dimensions:

1. *Who received health services?*

   The infrastructure must capture information about individual(s) who have diseases, receive vaccinations, and/or are exposed to environmental hazards.
2. *Who provided the health services?*

   The infrastructure must capture information regarding provider(s) who diagnose a person with a disease/condition/exposure and/or provide treatment to a patient.
3. *Where were health services received?*

   In a fragmented health care delivery system, patients are treated at numerous locations. The infrastructure must capture information describing the location where diagnosis occurred, treatment was performed, and/or the individual was exposed.
4. *What specific care was provided?*

   The infrastructure must capture information on what happened during an encounter. What vaccine was given? What was the laboratory result that confirmed a suspected diagnosis? How was the environmental exposure identified?

The architecture in Fig. 5.1 depicts several technical components that enable a public health organization to capture, store, manage, and share information across the four key dimensions. The architecture is based on the *service-oriented architecture (SOA)* concept in which discrete, interoperable services function together as an information system. Each component of the architecture can be a different software application or Web-based service. While each component plays a critical role, the sum of the system is greater than its individual parts.

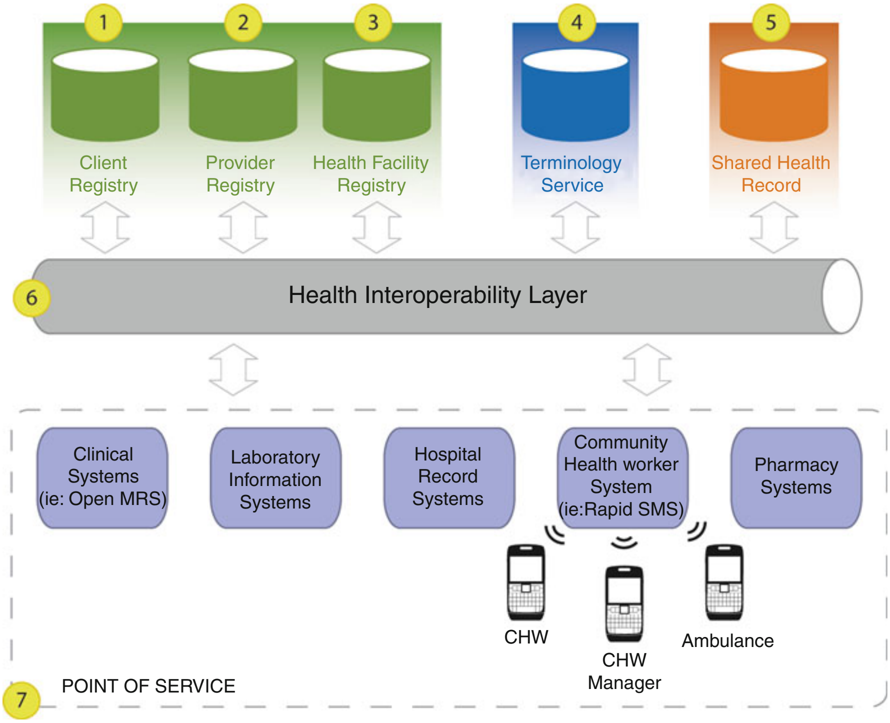

Fig. 5.1 A technical infrastructure for public health (Copyright © 2013 OpenHIE. All Rights Reserved. Used with permission)

We now describe each component and how it relates to the other parts of the architecture.

1. An *enterprise master patient index (EMPI),* or Client Registry manages the unique identity of people receiving health services or diagnosed with disease – "For whom"
2. A *Provider Registry* is the central authority for maintaining the unique identities of health providers– "By whom"
3. A *Health Facility Registry* serves as a central authority to uniquely identify all places where health services are administered – "Where?"
4. A *Terminology Service* serves as a central authority to uniquely identify the clinical activities that occur within the care delivery process by maintaining a terminology set mapped to international standards – "What?"
5. A *Shared Health Record (SHR)* is a repository containing the normalized version of content created within the community, after being validated against each of the previous registries. It is a collection of person-centric records for patients with information captured by the health agency.

6. A *Health Interoperability Layer* receives all communications from point of service applications within a specified population, and orchestrates message processing among the point of service application and the hosted infrastructure elements. Other industries refer to this as an enterprise systems bus (ESB).
7. *Point of service applications*, such as an electronic health record (EHR), laboratory information systems, and mHealth applications, are used by clinicians and by other clinical workers to access and update person-centric shared health information and record healthcare transactions.

Furthermore, this architecture is flexible, allowing health departments to add other point of service applications, such as a syndromic surveillance system, or a different kind of data store, such as a de-identified repository of survey data, to the architecture. The SOA approach enables many kinds of applications, services, and repositories to co-exist, provided they are integrated in a manner that allows them to leverage and be leveraged by the rest of the architecture. A health department may have use for multiple kinds of repositories for various legacy (e.g., vital records system) and new (e.g., social media) data types. As long as the repositories are exposed through the interoperability layer to apps and services, an infinite number of options are available for deployment. We now illustrate how the technical architecture supports selected public health functions.

Immunization Records

An immunization information system (IIS, also known as immunization registry) is a classic example of a public health informatics application. An IIS maintains a longitudinal, person-centric record of immunizations given to an individual over his or her lifetime and supports providers in delivering age-appropriate immunizations, leading to improved vaccination coverage. The main functions of IISs are to:

1. Consolidate immunization data from disparate sources;
2. Provide patient-specific vaccine forecasting/decision support based on known immunization history and patient age;
3. Support the creation of reminder and recall notices;
4. Support proper vaccine inventory management; and
5. Generate vaccination coverage assessments.

IISs exist in most states, and, as of 2011, 84 % of US children aged <6 had two or more immunizations recorded in an IIS [19]. IISs are adept at receiving both batch and real-time information from clinical information systems, in a variety of formats, but rarely provide two-way, real-time information exchange and synchronization between EHRs and the IIS [20]. For example, clinicians often access IISs through standalone applications, independent of their EHR systems, in order to view patient immunization histories and vaccine forecasts. Stage 2 Meaningful Use regulations issued in 2012 from CMS require EHR systems to exchange immunization data with IISs starting in 2014. These new regulations may result in more bidirectional exchange between EHR systems and IISs.

Bidirectional exchange requires that the public health technical infrastructure be capable of receiving and sending messages with clinical and other health information systems. When a message arrives at the health department, it must pass through the health interoperability layer (#6 on Fig. 5.1) and match to a patient record in the shared health record (#5 on Fig. 5.1). This is facilitated by a call to the client registry (#1 on Fig. 5.1), which attempts to link the incoming message to an existing patient. If no match is found, then a new patient record can be created. Next, the health interoperability layer matches information in the immunization message to data in the provider (#2 on Fig. 5.1) and facilities registries (#3 on Fig. 5.1), respectively. Here the system seeks to ensure that the provider administering the immunization and the facility in which the immunization was given match to known providers and facilities in the jurisdiction. Finally the system calls the terminology service (#4 on Fig. 5.1) to match the information about which immunization(s) were administered to the patient or the reason(s) for refusal. Standardized vaccine data, such as CVX codes developed and maintained by the CDC, provide the name of the vaccine along with the manufacturer name and lot number [21]. Once the various parts of the incoming message have been matched to client, provider, facility, and terminology data, the information in the message can be stored in the shared health record. The infrastructure now supports storing millions of immunization events in the shared health record along with other existing information about the individuals – such as birth certificate records.

The other function of an IIS is to provide decision support to providers, informing nurses and physicians when a patient is overdue for certain immunizations (e.g., pneumovax for adults over 65). A shared public health infrastructure can support this through an interface with the IIS [19]. A physician can use the IIS to query the infrastructure to receive an immunization history and recommendations on overdue items. The IIS calls the health interoperability layer, which uses the client registry to locate all immunization records in the shared health record for the selected patient. The raw immunization records are then passed back to the IIS, which can deliver them to the requesting physician along with recommendations derived from the shared health record. The IIS and infrastructure work together to manage person-centric immunization data.

Electronic Laboratory Reporting

Electronic laboratory reporting (ELR) involves the transmission of laboratory data, following the confirmation of a reportable disease, to a public health agency. ELR has been used successfully in a number of cities, states, and nations to improve public health surveillance [22, 24]. Public health agencies that have implemented and used ELR report a number of benefits. First, notifiable disease reports that arrive electronically arrive faster than the previously used paper-based reports [22, 24, 25]. Second, ELR has been shown to increase completeness or the proportion of reportable disease reports that are transmitted to public health [22–25]. Thus ELR addresses the problem of underreporting of reportable disease cases [26, 27].

Currently, more than 40 states in the US have some capacity to receive electronic reports from laboratories [28]. Given previously variable adoption rates, routine ELR was made a requirement under Stage 2 Meaningful Use regulations. Laboratory information systems are required to electronically submit laboratory results to EHR systems for delivery to clinicians, and hospitals must electronically report laboratory results for notifiable disease cases to public health departments [13]. The CDC and other public health organizations anticipate the regulations will significantly increase ELR adoption [14].

ELR can leverage a common public health infrastructure by connecting lab information systems to the health interoperability layer. As lab messages arrive, the patient, provider, and facility information can be matched to respective records in the client, provider, and facility registries. The vocabulary service interprets the Logical Observation Identifiers Names and Codes (LOINC®) codes, which identify the test performed by the laboratory [29], and the Systematized Nomenclature of Medicine-Clinical Terms (SNOMED CT®) codes, which identify organisms, substances, diseases, and other findings from the lab test [30]. Data from the ELR messages could then be stored in the shared health record, linking multiple tests performed on the same individual to aid in case investigation procedures. The shared health record would also link ELR information to immunization history and other clinical observations known by the health department about an individual. Other information systems in the health department could query or extract data from the shared health record to aggregate counts of reported disease or examine relationships between immunization history and diagnoses for vaccine-preventable disease.

Syndromic Surveillance

Syndromic surveillance detects initial manifestations of disease before diagnoses (clinical or laboratory) are established [5–7]. Data and information in syndromic surveillance systems come from a variety of sources, including hospital emergency department visits, ambulatory clinic visits, school absenteeism, poison control centers, and over-the-counter medication sales [26]. Data are usually reported as de-identified lists or aggregate counts of cases due to laws that prohibit sharing identified data (e.g., Family Educational Rights and Privacy Act [FERPA] does not allow schools to provide identified child records).

According to a survey conducted by the International Society for Disease Surveillance, around 80 % of state and territorial health departments in the US performed some form of syndromic surveillance as of 2007–2008 [31]. The United Kingdom [32], Armenia [33], Taiwan [34], and New Zealand [35] have also implemented syndromic surveillance systems, and there is growing interest in these systems in low and middle-income nations [36].

Syndromic surveillance, like ELR, poses several challenges for public health agencies. A primary challenge is coordination and integration of syndromic surveillance systems. A report by the US Government Accounting Office describes 19 surveillance systems, as of 2004, in use at the state and federal levels [37]. These systems have a need to talk with one another [26], either to exchange information between levels of government or integrate multiple syndromic indicators into a single "view" of a community or region. These systems, however, do not all use a single messaging platform that enables easy integration, and data standards that enable semantic interoperability remain a challenge.

Use of a common infrastructure within a health agency may be a solution to some of these challenges. Incoming messages could be passed to the health interoperability layer, which could resolve provider and facility identifiers in the messages using the respective registries. The client registry would not be used when syndromic information is de-identified. The vocabulary service can support grouping messages – which typically contain open-ended text – into syndrome categories for use by the surveillance system. Syndromic data could also be passed directly to the syndromic surveillance system, or stored in a separate repository.

Storing data in the shared health record would be suboptimal given that patient identities are obfuscated or absent. A constrained shared repository for managing de-identified surveillance data could enable the data to be utilized by multiple applications within the health department instead of just a surveillance system designed specifically for syndromic information. For example, population health assessments or surveys, like the Behavioral Risk Factor Surveillance System (BRFSS), which capture de-identified data on populations, would be supported by the constrained data repository. Co-located population data could be combined by point of service applications to explore social determinants of health [38] or multi-source surveillance activities [39, 40].

Bidirectional Communication

Public health has a responsibility to both monitor disease and inform the community on events involving disease spread and management. Thus the public health infrastructure requires the capacity to both receive data from health care information systems and deliver information to clinical systems. In other words, the public health infrastructure needs to support bidirectional communication with EHR and other health information systems. Informing front line clinical staff about population health outcomes and events using a common infrastructure is form of public health decision support [41].

Currently health departments often communicate community-level information or statistics to physician offices and hospitals using postal mail or electronic newsletters [42]. As the public health infrastructure becomes more interoperable, bidirectional communication from public to clinical health information systems is likely to increase [41]. The common infrastructure we describe supports bi-directional communication in a variety of scenarios, such as:

1. *Public health alerts*, used to raise a clinician's index of suspicion for known or as of yet unidentified disease or condition emerging in the community. For example, one study utilized a common clinical infrastructure outside the EHR to deliver guidance and information on vaccine supply management to primary care clinicians during the H1N1 outbreak [43]. Other studies have examined methods for pushing alerts directly into EHR systems based on increased reports of shigellosis or another reportable disease [44, 45].
2. *Routine population health statistics* to support healthcare organizations and their increasing responsibilities for patient population health management. By making health statistics and research results more readily available to support clinical decision-making, both the clinician and the patient are enabled to make better-informed decisions about a course of treatment.
3. *Person-specific case management* or other information to support coordinated care management between clinical and public health.

A common infrastructure in public health can support knowledge repositories and applications that push alerts and information out to providers using the health interoperability layer. Provider and facility registries can contain electronic addresses for providers that enable routing of messages both to and from clinical information systems.

The Indiana Network for Patient Care: A Real-World Instantiation of a Robust Information Infrastructure Supporting Public Health Processes

The Indiana Network for Patient Care (INPC) is the nation's longest-tenured and most comprehensive health information exchange (HIE). Researchers at the Regenstrief Institute created the INPC in 1995 with the goal of providing clinical information at the point of care for the treatment of patients [46, 47]. The architecture of the INPC inspired the technical architecture described in this chapter, and the INPC remains an active technology laboratory influencing the evolution of the public health infrastructure given the examples below where the HIE is used to support a wide range of public health functions.

The INPC includes clinical data from more than 49 hospitals; local and state health departments; local and national laboratories; a national pharmacy benefit manager (PBM) consortium; long term post-acute care (LTPAC) facilities; free standing radiology centers; emergency management services (EMS); and several large-group practices closely tied to hospital systems. The INPC data repository carries over 4.3 billion pieces of clinical data, including over 79 million text reports, for approximately 25 million different patient registrations totaling approximately 12 million unique patients.

The primary use of the INPC is to improve communication and decision-making in the context of individual patient care. However, because the INPC standardizes incoming clinical and administrative data, the HIE enables a wide range of secondary uses, including public health reporting and syndromic surveillance [46, 48]. For example, clinical laboratory test results are mapped to a set of common test codes (e.g., LOINC®) with standard units of measure for use in patient care (e.g., displaying all blood lead level measurements chronologically in a table or chart for clinician review), public health (e.g., identifying elevated blood lead levels in pediatric patients reportable to public health), and research (e.g., extracting address data for patients with elevated lead levelsand integrating such information with the geographical locations from environmental studies identifying elevated soil lead levels). These are similar activities to those in health departments around the world, and the INPC often partners with local and state health departments to facilitate access to data they need to support the core functions of public health.

Since 1998, the Regenstrief Institute has maintained an operational, automated electronic laboratory reporting (ELR) system [49] called the Notifiable Condition Detector (NCD) as a service provided by the INPC. The NCD identifies clinical results that are positive for reportable conditions and automatically reports them to both local and state health departments in near real-time, as well as providing daily aggregate counts for all reportable conditions found. Data sources (hospital, state health, and referral laboratories) transmit results to the INPC in electronic format. The NCD processes incoming ELR messages using Logical Observation Identifiers Names and Codes (LOINC®) codes [29], ICD-9 diagnoses, and natural language processing [50] to determine if a test is potentially reportable, and the NCD uses the CDC reportable condition mapping table [51] to verify reportable conditions. Final results are shared with health agencies in a variety of formats including Health Level 7 (HL7®) and comma delimited files (CSV), based on the jurisdiction's technical capacity. The NCD is a freely available component of Regenstrief's Open Medical Record System (OpenMRS) platform, which enables implementation and use by health care providers in over 100 nations around the world [52–54].

The INPC has further supported efforts to increase infection preventionists' (IP) awareness of patients' MRSA infection history and reduce the spread of healthcare acquired infections (HAIs) in INPC facilities. Over the course of 1 year, we found that 286 unique patients generated 587 admissions accounting for 4,335 inpatient days where the receiving hospital was not aware of the prior history of methicillin-resistant *Stapylococcusaureus*(MRSA) [55]. These patients accounted for an additional 10 % of MRSA admissions received by study hospitals over 1 year and over 3,600 inpatient days without contact isolation. To improve physician and IP awareness of patients who should be in contact isolation given a history with MRSA or vancomycin-resistant *enterococcus* (VRE), we first developed and implemented a clinical reminder to alert physicians when a patient on the contact isolation list did not have a standing order for contact isolation [56]. Then, we expanded this innovation to the INPC, alerting IPs when patients who had a history of MRSA or VRE were admitted to their facilities [57, 58]. In the first year, the INPC delivered 2,698 admission alerts for patients with a history of MRSA, one-fifth of which (19 %) were based on data from a different institution.

Managing the Public Health Infrastructure: The Role of Organizations

Public health organizations manage the public health infrastructure. They carry out their duties in three ways:

1. By *creating and enforcing policies*, public health organizations define the scope of the public health infrastructure.
2. By *organizing work*, public health organizations define the business processes that drive the public health infrastructure.
3. By *managing people*, public health organizations define how and when the workforce can access and use public health data and information.

The work performed by public health agencies is diverse and expansive in nature. The Institute of Medicine [59] defines three core functions of public health:

1. Assessment and monitoring of the health of communities and populations at risk to identify health problems and priorities;
2. Formation of public policies to solve identified local and national health problems and priorities; and
3. Assurance that all populations have access to appropriate and cost-effective care, including health promotion and disease prevention services, and evaluation of the effectiveness of that care.

The nature of public health is shifting in the twenty-first century. Whereas public health activities have largely focused on monitoring and intervening in the spread of communicable diseases (e.g., polio, tuberculosis, HIV/AIDS), chronic and environmental threats are increasing in prevalence. Therefore while agencies must continue to record data on the spread of infection and fight emerging diseases that spread quickly, efforts at many public health organizations are expanding into community-based interventions to improve self-management of chronic illness and complex physical/social/behavioral interventions to prevent environmental and chronic disease in healthy populations. Furthermore, the Patient Protection and Affordable Care Act (PPACA) of 2010 requires private ACOs to conduct annual population health assessments, blurring the traditional line between private and public health organizations [11].

Therefore the technical infrastructure described here is a suggested core designed to support a wide range of public health functions. However, unique laws, regulations, and requirements of a given public health organization may necessitate amendments or additions. As new policies are enacted that change the nature of public health work, the infrastructure that supports public health will need to be amended.

This point is illustrated in the National Institute of Standards and Technology's Enterprise Architecture Model, which emphasizes that an organization's business processes should drive its infrastructure [60]. Effective management of the public health infrastructure will require organizations to understand its business processes and the needs of public health workers. Otherwise, health departments will suffer the same fate as the one in New Jersey, where the introduction of ELR led to a significant increase in the completeness of disease reports, but it "exceeded local investigative capacity" [61].

Business Process Analysis and Redesign

A business process describes a set of activities and tasks that logically group together to accomplish a goal or produce something of value for the benefit of the organization, a stakeholder, or a customer [62]. In the context of public health, a business process is intended to support the needs of the health agency, community, or a target population. Because information technology and services facilitate business processes, a clear understanding of these processes is needed to ensure that public health informatics strategies will result in maximally effective and efficient support of public health needs.

Documenting business processes and re-designing them to meet the challenges associated with (a) the shift from acute to chronic disease surveillance and (b) increasing electronic data flows from clinical health, can be achieved using business process analysis (BPA). BPA gathers information from stakeholders about existing processes with an eye towards redesigning them to improve efficiency or enhance the value they produce. This technique has been utilized by the Public Health Informatics Institute (PHII) to redesign and enhance multiple business processes in the context of public health. For example, PHII has defined functional requirements for immunization information systems [20, 63] and public health surveillance [64]. BPA is further recognized and recommended as a best practice for achieving the Public Health Informatics agenda [18].

User-Centered Approach

In addition to analyzing and redesigning business processes, public health organizations need to understand end users' (public health workers') information needs [65]. Asking and involving users in the design, development, and implementation of the infrastructure will maximize the likelihood that ICT in agencies meets not only the business needs but also the context of use.

User-centered approaches require early and frequent involvement of frontline public health workers. When designing a system or process, workers should be asked about their needs. Low fidelity prototypes or wireframes can be used to elicit and identify user needs before any system engineering work has been done [66], reducing cost to make changes after implementation. If purchasing a commercial system, users can review screenshots, process diagrams, and interact with demo systems to provide feedback to the group in the organization making purchasing decisions. Usability testing can also be performed where end users attempt to complete certain tasks using an information system [67]. Vendors can be asked to make a test or demo system available to the organization for such testing during the evaluation process if specified in request for proposal documentation.

Managing the Public Health Infrastructure: The Public Health Workforce

People are the third critical component of the public health infrastructure. Managing the infrastructure requires public health organizations to ensure their workforces are knowledgeable and capable. In the modern era, the public health workforce requires competencies in informatics. Organizations must train and prepare two types of staff: end users and public health informaticians. End users are epidemiologists, communicable disease nurses, food safety inspectors, and others on the front lines of public health who *interact with information systems*. Public health informaticians are those who help organizations *design, manage, and evaluate information systems and work processes*.

Public Health Informaticians

The role of a public health informatician is defined by consensus-based competencies [68, 69] from the CDC, Association of Schools of Public Health (ASPH), and American Medical Informatics Association (AMIA). Public health organizations must hire or train informaticians to meet their informatics needs. An emerging, increasingly necessary role within a public health organization is a Chief Public Health Informatics Officer. This management or executive position bridges the gap between public health program areas, the ICT department, and the senior health officer.

Currently there is a paucity of these officers in local and state health departments. Consequently, there is great need to train and mentor epidemiologists and other senior program officials into informatician roles. The CDC and public health professional organizations are currently working to identify and prepare epidemiologists and other senior program officers to become informaticians. In the future, it will be critical for these and other existing public health informaticians to mentor junior informatics-trained individuals in their region or across jurisdictions. ASTHO and CDC have created public health informatics internship programs to provide experiential learning opportunities for individuals with training in informatics. It is likely the US will need many of these types of programs. Furthermore, model job descriptions are needed to ensure consistency in the role of public health informatician across jurisdictions.

Public Health End Users

The growing need for public health informatics competencies will further require schools of public health to produce available candidates for positions that will work to modernize information systems and strategically align information needs with work processes. Faculty in public health schools will either need to create informatics concentrations or specializations within epidemiology degree programs, or they may collaborate with schools of information, computing, or informatics to offer joint majors or minors in public health informatics. These programs will provide modern competencies to emerging public health professionals, which can be leveraged by departments to train existing personnel.

Public health professionals across the infrastructure will need some understanding of informatics, ICT, and how information is central to work processes. Such core knowledge as a component of training in public health will help the workforce collaboratively work towards improving public health systems and population outcomes.

Conclusions

The public health infrastructure requires a skilled public health workforce, robust ICT, and effective organizations. In this chapter we have reviewed a model ICT architecture, examples where information systems are supporting effective public health practice, key informatics factors for managing organizations, and important informatics aspects of the workforce. These dimensions of the public health infrastructure are complex and evolving. One thing that is clear is the public health infrastructure will change as health reform is implemented and additional information systems are adopted in both clinical and public health. The principles and lessons in this chapter, however, should help guide informaticians seeking to design, implement, evaluate and evolve ICT across the public health infrastructure.

Review Questions

1. Describe the three components of the public health infrastructure. How do the interconnected systems that define the public health infrastructure work together to support public health practice?
2. What challenges does the public health infrastructure face, and how can public health organizations respond to these challenges?
3. Describe four dimensions of health data. How can a technical infrastructure supporting these dimensions be leveraged across public health use cases, such as immunization registries and communicable disease case reporting?
4. Describe how population health assessment data could be integrated into a common public health infrastructure operating in a county health department. What new data sources, repositories, or applications would be involved in the integration?
5. How can public health agencies leverage community-based health information exchange initiatives to support their mission of population health monitoring and improvement?
6. Describe how a public health organization might redesign its communicable disease reporting processes to manage a significant increase in electronic laboratory reports.
7. What are the roles of a public health informatician in building and enhancing the public health infrastructure?
8. Define business process analysis and its role in supporting public health infrastructure.
9. How has growth in EHR systems and health information exchange impacted the nature and volume of information, and how has this growth impacted public health data gathering processes?

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