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CHAPTER

The Healthcare System

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1. INTRODUCTION

The healthcare system plays an enormous role in biosurveillance. Its importance derives from a simple fact: when people contract infectious diseases, they seek medical attention.

The healthcare system comprises hospitals, doctor's offices, long-term care facilities, visiting nurse services, laboratories, dental offices, pharmacies, ambulatory and "same day" procedure facilities, and emergency medical services. All of these organizations are involved in the assessment and care of the sick.

Hundreds of thousands of highly accessible nurses, licensed nurse practitioners, and physicians work in healthcare. These frontline healthcare workers are trained to accurately observe and interpret diagnostic information. They are skilled at eliciting and recording basic elements of an epidemiological case history, and they routinely record data needed for outbreak detection and for characterization. These data include symptoms of disease, temperature, laboratory results, and diagnoses.

At present, the healthcare system plays three roles in biosurveillance. First, the healthcare system reports notifiable diseases and clusters of suspicious illness to state and local health departments. Second, the healthcare system assists outbreak investigators by providing medical records, screening services, and diagnostic work-ups of patients. Third, the healthcare system conducts biosurveillance of its own facilities (especially hospitals and long-term care facilities). Hospitals operate special divisions called *infection surveillance and control units* that monitor a facility for patients with communicable diseases and for outbreaks. Outbreaks can start or spread quickly in healthcare facilities and then spread to the community, as they frequently did during the 2003 severe acute respiratory syndrome (SARS) outbreak.

At present, the domains of medical and epidemiological practice exchange relatively little data, except in the setting of an outbreak. They exchange these data primarily by fax, mail, telephone, and e-mail and e-mail attachment. These mechanisms of communication are vulnerable to errors of omission and delays. Even when these domains use electronic transfer of data, the exchange is typically via batch transfer of data on a daily or less frequent basis, rather than via a real-time communications.

In the future, the healthcare system will provide significantly more data and services to governmental public health, and it will provide the data in real time. Indeed, this "megatrend" is already unfolding in many jurisdictions in the United States and abroad. Conversely, governmental public health will transmit case definitions and up-to-the-minute information about disease prevalence electronically to the healthcare system. The untapped potential for biosurveillance of real-time electronic communications among the healthcare system and other biosurveillance organizations, such as governmental public health, is enormous, as we will discuss.

2. ORGANIZATION OF THE U.S. HEALTHCARE SYSTEM

As every American knows, the healthcare system in the United States comprises many independent organizations, with an estimated 5,000 hospitals, 17,000 long-term care facilities, and 40,000 pharmacies. There are countless office practices, free-standing radiology practices, and commercial laboratories. There has been a trend toward consolidation of these entities over the past two decades. Some of the bigger consolidations include pharmacy chains, laboratories, the military healthcare system, the healthcare system run by the Veterans Administration (VA), and large health maintenance organizations such as the nine Kaiser Permanente health maintenance organizations. Nevertheless, the number of independent organizations remains large.

Hospitals themselves are subdivided into many somewhat independent departments, including laboratory, radiology, pharmacy, and clinical departments (e.g., infectious diseases). Each of these divisions may operate its own information systems, which is both a blessing and a curse. It is a blessing because the information systems collect data relevant to biosurveillance, and it is a curse because the sheer number of information systems imposes a barrier to data integration for biosurveillance (although as we will discuss, hospitals are

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motivated to integrate these systems for their own benefit and, to some extent, have already done so).

Of course, differences between healthcare in the United States and in other countries exist. Canada and the United Kingdom have national healthcare systems, which make more centralized decisions about information technology (IT). However, even in countries with national healthcare systems, the process of health care involves large numbers of individuals, facilities, organizations, and heterogeneity of information systems.

3. PERSONNEL

Most readers are quite familiar (perhaps more familiar than they would like to be) with the personnel that work in the healthcare system, such as physicians, nurse practitioners, nurses, pathologists, phlebotomists, medical technologists, radiologists, and a wide array of specialists. Readers may be less familiar with hospital epidemiologists and infection control practitioners, who are responsible for biosurveillance of the hospital. We discuss *hospital infection control* in more detail later in this chapter.

Readers may also not realize that hospitals employ a large number of specialists in IT. To function in the healthcare setting, these individuals require not only competence in their primary IT role but also an understanding of medical data and processes, which are complex. To function as part of a biosurveillance system, they similarly require a basic understanding of biosurveillance processes.

4. ROLE OF THE HEALTHCARE SYSTEM IN BIOSURVEILLANCE

Existing laws and regulations in the United States and other countries shape the role of the healthcare system in biosurveillance. As discussed in the previous chapter, health statutes in the United States require hospitals, physicians, and clinical laboratories to notify health departments whenever they encounter patients with notifiable diseases. In general, the body and spirit of American law promotes and enables the healthcare system to participate in biosurveillance. The recent Health Insurance Portability and Accountability Act (HIPAA) recognized the need of governmental public health to collect biosurveillance data from the healthcare system (and other organizations that collect personal health information). HIPAA exempts this use of personal health information from the scope of its regulations (Department of Health and Human Services, 2002).

Hospital infection control has traditionally been influenced more by scientific consensus and evidence than by laws and regulations.[1]

The informal influence takes the form of evidence-based guidelines and position papers. Many professional and governmental organizations—develop guidelines.[2]

Hospitals heed many of these guidelines based on their inherent merit. The JCAHO adopts some of them into its criteria for accreditation. JCAHO's standards have a profound influence on infection control practice and on the healthcare system in general, as we will discuss.

5. DATA COLLECTED BY THE HEALTHCARE SYSTEM

Similar to biosurveillance, the practice of medicine is information intensive. The healthcare system records many types of data for every patient encounter. Table 6.1 lists data that clinicians routinely record as part of the admission history and physical for each patient admitted to a hospital. They record similar data throughout an inpatient stay and for outpatient visits. If just these data were fully and immediately available to biosurveillance organizations for all patients seen by clinicians with possible infectious diseases, their ability to detect and characterize disease outbreaks would be enhanced considerably.

Access, however, is a significant barrier to the use of healthcare data in biosurveillance. Healthcare workers record many important data only on paper. The types of data that are most often "locked away" on paper are the very data needed for early detection and rapid characterization of an outbreak—a patient's symptoms, travel history, immunization history, history of recent foods consumed, and contacts with sick individuals or animals. This problem is especially severe in outpatient offices, which have lower levels of automation than do hospitals. This barrier to access will gradually disappear because of a number of trends, including the falling cost of IT, consolidation of the healthcare system, and federal initiatives such as the National Health Information Infrastructure (NHII) (Yasnoff et al., 2001, 2004; Rippen and Yasnoff, 2004).

Even when the healthcare system records data electronically (as is typically the case for results of laboratory tests and radiology examinations), the data are encoded in nonstandard formats that represent a barrier to regional integration of data for biosurveillance. This problem will also gradually resolve as the healthcare system adopts standard methods for representing and storing data (discussed in detail in Chapter 32, *"Information Technology Standards in Biosurveillance"*), a process that has been ongoing for several decades and is gaining momentum under NHII.

1 This situation is changing as a result of increased awareness of the societal cost of hospital-acquired infections in terms of morbidity, mortality, and economic costs. Recent JCAHO rules now hold the CEO of a healthcare organization accountable for ensuring adequate funding of infection control.

2 Influential organizations include the Society for Healthcare Epidemiology of America (SHEA), Association for Professionals in Infection Control and Epidemiology (APIC), and the Hospital Infections Control Practices Advisory Committee (HICPAC) of the CDC.

TABLE 6.1 Diagnostic and Epidemiological Data Recorded in an Admission History and Physical Examination

Type of Data	Examples of Data Relevant to Clinical Diagnosis (Case Detection), Outbreak Detection, or Characterization
Demographics	Age, gender, home and work address
History of present illness	Symptoms (cough, fever, diarrhea) and their timing; significant negatives
Physical examination	Temperature, rashes, evidence of pneumonia
Laboratory results	Blood, stool, and sputum cultures; cerebrospinal fluid analyses; examinations of stool for ova and parasites
Radiology results	Chest radiographs
Travel and exposure histories	Travel to endemic area, drinking of unboiled water, animal bites
Vaccinations	Measles, hepatitis, influenza, yellow fever vaccinations
Personal/social history	Intravenous drug use, sexual practices, occupation, household members
Past medical history	Diabetes, HIV, transfusions
Allergies	Medications, insects
Current medications	Ciprofloxacin, Tamovir
Diagnostic impression	"pneumonia, rule out anthrax"

Data are checked if they could be used in a case-control study to elucidate outbreak characteristics such as source or to determine if a patient matches a case definition.

6. INFORMATION SYSTEMS IN HEALTH CARE

Information systems are the key to solving the problem of accessing clinical data for biosurveillance. The past 3 decades have seen the emergence of electronic systems to manage almost every aspect of medical practice, including scheduling, ordering of tests, recording of clinical observations, and intensive care unit operations. Some of these systems are widely deployed; others have far less market penetration. To realize the potential of clinical data for biosurveillance, the market penetration of those systems that collect needed clinical data must increase (especially into outpatient settings) and the systems must be "biosurveillance enabled," which means they must provide certain functions and do so in a standard way.

Because of the enormous potential of data collected by the healthcare system for biosurveillance, we devote this lengthy section to a description of the information systems that the healthcare system presently uses to collect and store data. We have written this section with the needs of designers and developers of biosurveillance systems in mind. Therefore, in addition to describing the systems, we highlight data relevant to biosurveillance and any technical or administrative barriers to obtaining the data. We offer our opinion about which systems provide the most immediate and the most long-term potential for biosurveillance. We suggest questions that a biosurveillance organization should ask a healthcare system or hospital when discussing options for creating electronic data exchange. For readers that have limited time, our conclusion will be that HL7 (Health Level 7)-message routers offer the most immediate potential for bidirectional data exchange between biosurveillance organizations and the healthcare system, and that point-of-care (POC) systems represent the future of biosurveillance. Table 6.2 summarizes the systems that we will discuss—the data they contain, their market penetration, and their potential role in biosurveillance. As a general rule, the larger the hospital or healthcare organization, the more likely it will have each system.

6.1 HL7-Message Routers

Figure 6.1 illustrates the information-system architecture of a typical hospital (or multihospital system). At the heart of the architecture is an HL7-message router.[3] An HL7-message router is a communication hub that transmits information between information systems, both within the healthcare system and outside of it. HL7-message routers are commercial off-the-shelf products supplied by many vendors (there is an open-source HL7-message router called Jengine available at *http://www.jengine.org/* and an HL7 listener, which can receive messages from a hospital HL7-message router, at *openrods.sourceforge.net*). They are also called *integration engines.* Healthcare systems often employ HL7 interface engineers and network engineers to configure and maintain these systems around the clock.

The importance of the HL7-message router for biosurveillance is twofold. First, many clinical information systems send data to the HL7-message router (Figure 6.1). The data include patient chief complaints, dictations, results of laboratory tests, and results of radiological examinations. The information systems send these data to the HL7-message router in real time, and the HL7-message router can forward these data to biosurveillance organizations without delay. If a computer in a biosurveillance organization is temporarily incapable of receiving the data, the HL7-message router will queue the data for up to a week until the computer becomes available. Second, an HL7-message router can support bidirectional, real-time communication between computers in a healthcare system and computers in a biosurveillance organization by using the

3 The term *HL7* (Health Level 7) refers to the dominant messaging standard in health-care computing. Briefly, the *HL7* standard was developed in the 1980's by a coalition of information system vendors to allow their systems to more readily exchange data. We discuss the HL7 standard in detail in Chapter 32.

TABLE 6.2 Information Systems in Healthcare: Data, Relevant HL7-Message Types, U.S. Market Penetration (Estimated), and Potential Uses of the Data in Biosurveillance

			U.S. Market Penetration			
System	Data	HL7 Message Type and Event	Hospital/Health System	Office/Home Health	LTC Facility	Potential Biosurveillance Use
HL7-message router	Data from many of the systems listed below	N/A	High	Large HMOs	If owned by HS	Best current single point of integration
Registration	Chief complaints, addresses, age, sex	ADT^A04	High	?	—	Source of data for case detection, syndromic surveillance
Billing	Diagnostic and procedure codes (CPT codes, ICD-9 codes)	DFT^P03	High	High		Source of data for case detection, syndromic surveillance
Laboratory	Orders and results of tests	ORM^O01 (orders) ORU^R01 (results)	High	High	High	Culture- and test-based detection strategies
Dictation	Symptoms, signs, travel, exposures	MDM^T02	High			Source of symptom and sign data
Radiology	Orders and results of tests, images	ORM^O01 (orders) ORU^R01 (results)	High	High		Test-based strategies
Pathology	Orders and results of tests, autopsy results	ORM^O01 (orders) ORU^R01 (results)	Mod	Mod		Diagnosis-based strategies
Pharmacy	Orders for medications	RDE^O01	High			Indirect evidence
Order entry	Orders for laboratory tests and medications; admission diagnoses	Refer above message types and events	Moderate	Low	Low	Indirect evidence
Point-of-care systems	Symptoms, vital signs, signs, diagnoses, orders, epidemiological data	?	Low	Low		Data needed to satisfy case definitions; potential for decision support for physicians
Data warehouse	Data from many of the systems listed above	N/A	Low	—	—	All of the above
Call centers and patient Web portals	Symptoms, referrals, appointments	N/A	Low	—		Collect early symptom information, potential for decision support for patients

LTC indicates long-term care facility; HMO, health maintenance organization; HS, hospital system; ADT, admission discharge and transfer; ?, unknown; —, not applicable; CPT, Current Procedural Terminology; ICD-9, International Classification of Diseases 9th edition.
Adapted from Agency for Healthcare Research and Quality report.

query message type.[4] For these reasons, HL7 messaging is a core element of emerging biosurveillance IT standards, as we discuss in Chapter 32. It is worthwhile to point out that HL7 defines a communications protocol at the application layer and does not address the transport layer (e.g., TCP/IP, HTTP, RS-232). Therefore, it is possible for two systems to speak HL7 at the application layer but still not be able to physically communicate.

Healthcare organizations that own multiple hospitals and physician practices may use an HL7-message router to integrate the data systems of these geographically diverse practices. In these settings, the HL7-message router represents a single point of integration between a biosurveillance organization and scores of hospitals. For example, when the Utah Department of Health deployed the RODS system for the 2002 Winter Olympics, it created a single connection to the Intermountain Healthcare System HL7-message router, enabling it to collect registration data from nine emergency departments and 19 acute care facilities (e.g., urgent cares, instacares and now cares). It created a second connection to the University of Utah HL7-message router to add one emergency department, one urgent care, and the polyclinic located in the Olympic Village to the biosurveillance system (Gesteland et al., 2002, 2003, Tsui et al., 2002).

Regarding data exchange with a hospital or other large healthcare organization, key questions to ask about HL7-message routers are as follows: *Do you have an HL7-message router (you may have to ask the IT person and remember that it is also called an integration engine)? Which information systems send messages to it? How many hospitals and office practices are connected to it? Do you maintain it, or do you outsource its maintenance? What is your minimum lower level protocol (e.g., TCP/IP, HTTP, RS-232) for HL7 messages if you have an HL7-message router?* Note that these and questions that we suggest for other information systems may best be answered by the healthcare organization's IT staff, and in many instances, they are best answered by the organization's HIS vendor.

4 There are multiple HL7 query message types such as QBP^Q21 (query for person demographics), QRY^Q28 (query for pharmacy dispense information), VXQ^V01 (query for vaccination record).

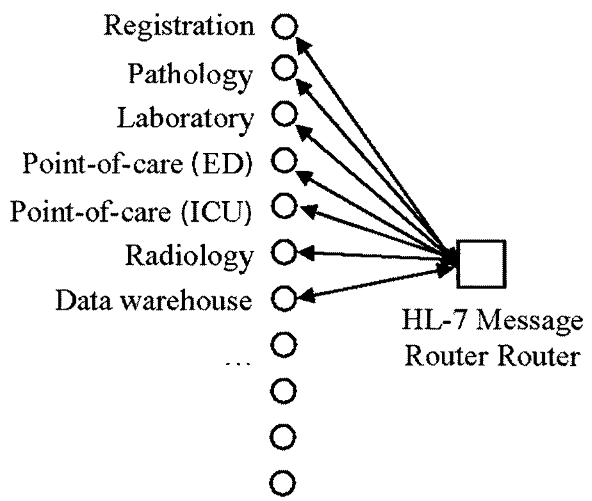

FIGURE 6.1 Representative information system architecture of a modern healthcare system. A healthcare system may also create direct connections between systems such as the laboratory information system and a point-of-care system (not shown).

6.2. Registration Systems

Clerical staff in emergency departments (and other medical facilities) register patients electronically at the time that they present for care. Electronic patient registration is nearly ubiquitous in the United States, especially in emergency departments and hospital-based or hospital-associated office practices and large health maintenance organizations. The registration clerk enters the reason for visit (also called the *chief complaint*) at the time of registration, along with the patient's age, gender, and home address. Syndromic surveillance systems analyze de-identified versions of these data (without patient name and with home address information limited to zip code) (Espino and Wagner, 2001; Lober et al., 2001; Tsui et al., 2001; Wagner et al., 2001).

The main advantage of registration data for biosurveillance is its widespread availability in the United States and inherent timeliness. If a healthcare organization has an HL7-message router, chances are good that the registration system sends messages to it and that it can de-identify and forward these data to a biosurveillance organization in real time.

6.3. Billing Systems

Billing was one of the first hospital functions to be computerized. Billing systems contain information about diagnoses and tests that were performed (but not the results). Third-party payers such as insurance companies require that a hospital encode this information by using either Current Procedural Terminology (CPT) or International Classification of Diseases, 9th edition (ICD-9) codes, a process that in many healthcare settings is done manually by professional coders. This process may introduce a several-day delay between the time the patient is seen and the diagnoses are available in a billing system. Billing data are often routed through an HL7-message router, and the combination of the widespread availability of both billing systems and HL7-message routers makes billing data highly available for biosurveillance. We note that third-party payers consolidate billing data from many hospitals and healthcare providers. Because the number of payers is typically smaller than is the number of hospitals and healthcare providers in a community, payers are a potentially more efficient source of billing data.

6.4. Laboratory Information Systems

A laboratory information system receives and stores requests for tests, and results are entered by laboratory technicians or directly from laboratory instruments (e.g., via the ASTM E-1381 protocol *Specification for Low Level Protocol to Transfer Messages between Clinical Laboratory Instruments and Computer Systems*). Results of tests are available via paper reports and electronic interfaces, both to human users and to other information systems such as a POC system (described below).

Laboratory information systems in hospitals, the animal health system, governmental public health, and commercial free-standing laboratories are virtually identical. For this reason, we devote Chapter 8 to the role of laboratories and networks of laboratories in biosurveillance.

Briefly, laboratories perform tests that include all types of cell counts, analytical chemistry, drug and toxin screening, and detection of microbes. The results of these tests are important to biosurveillance of virtually every conceivable biological agent. Fortunately, the vast majority of clinical laboratories in the United States are highly automated, using computers to perform tests, store results, and communicate results. Test results are generally available electronically very soon after the tests are performed. Results are available not only directly from the laboratory information system but may also be transmitted to an HL7-message router and to an enterprise data warehouse or a POC system (described below). There are many examples of hospitals that send laboratory data electronically to health departments, although these hospitals represent but a tiny fraction of the approximately 5,000 hospitals in the United States (Effler et al., 1999; Overhage et al., 2001; Hoffman et al., 2003).

Not only are the results of laboratory tests of value to biosurveillance, but so may be the mere fact that a particular test was ordered. The type of test ordered provides a clue to the clinician's diagnostic thinking about the nature of the illness in a patient, and it may be available well in advance of the result of the test, possibly within minutes or hours of a physician first seeing a patient.

At present, unfortunately, obtaining laboratory results from hospitals requires extensive custom interface development to translate and reformat data. Many hospitals use proprietary coding schemes to represent the names of tests and the results of tests. For example, the organism *Bacillus anthracis* may be called ANTX in one institution and BANTHRACIS in another. Dr. Clem McDonald recognized this importance of this problem in the 1980s. He promulgated the use of standards for the naming of laboratory tests and the reporting of their results (discussed in detail in Chapter 32). Until these standards are more universally used in health care, however, the construction of biosurveillance systems that collect laboratory data from hospitals will be time-consuming and expensive (the monitoring of laboratory test results and orders from national laboratory companies is far more feasible at present, as we discuss in Chapter 8).

When discussing data exchange with a hospital or other healthcare organization, the key questions to ask about the laboratory information system are as follows: *Does your laboratory information system use SNOMED and LOINC? Do you send the results to an HL7-message router, a data warehouse, or a POC system? Is the microbiology outbound feed structured (i.e., not a free-text report intended for printing or display on a computer screen only)?*

6.5. Dictation Systems

Dictation systems are a mainstay of clinical data recording in the hospital, emergency department, and outpatient settings. Clinicians often use dictation systems to record a patient's history, observations made during physical examination, progress notes, interpretations of radiological examinations, and results of postmortem examinations. Dictation systems can range in complexity from a single part-time transcriptionist working with a word processor to pools of transcriptionists using dedicated systems produced by companies such as Lanier. Although dictations are rich with clinical detail—including the patient's presenting complaint, the history of the illness, exposure information, vaccinations, vitals signs and physical findings, and diagnostic impressions—the data are recorded in English and are difficult for computers to understand. In addition, the time delay between dictation and transcription delays the availability of the data. Nevertheless, the value of the information is sufficiently high for both biosurveillance and medical applications that researchers in medical informatics have developed approaches to processing these data, which we discuss in detail in Chapter 17, *"Natural Language Processing for Biosurveillance."*

The availability of dictations for biosurveillance purposes is lower than that for laboratory data because not all transcribed dictations are stored electronically in databases and not all institutions route electronic versions of the transcriptions through an HL7-message router. Thus, even when dictations are available electronically, custom interfaces may need to be built to the database that stores the dictations.

When discussing data exchange with a hospital or other healthcare organization the key questions to ask about dictations are as follows: *Do you have a dictation system that produces electronic copy? Does it provide an outbound interface (either HL7 or proprietary)? Do you send the dictations to the HL7-message router, the data warehouse, or a POC system? Which of the many types of dictation are stored by the system, and with what time delay do they appear from the time of dictation?*

6.6. Radiology Systems

Radiology departments were early adopters of IT, and today many practices manage the reports of examinations electronically. A radiology department performs radiographic, ultrasound, computed tomography (CT), magnetic resonance imaging (MRI), and other examinations of patients. The results of many of these examinations are highly relevant to biosurveillance. Clinicians use radiological examinations to diagnose infectious diseases (e.g., pneumonias). The reports include the diagnostic impression of the radiologist (e.g., "the combination of mediastinal widening and pneumonic infiltrate is consistent with pulmonary anthrax"). Unfortunately, in the majority of practices, the radiologist dictates his report and it is subsequently transcribed; thus, the reports can be delayed a day or more by the transcription process and are transcribed in English (or another language). Researchers in medical informatics have investigated methods for processing dictated radiology reports to extract information about patient characteristics, such as presence or absence of pneumonia (see Chapter 17) (Jain et al., 1996; Knirsch et al., 1998; Chapman and Haug, 1999; Hripcsak et al., 1999; Fiszman et al., 2000a).

We note that technical advances have made it possible for radiology information systems to store the images themselves in digital form, although the market penetration of this functionality is relatively low at present with the exception of imaging modalities such as CT and MRI, which are inherently digital. Rapid access to the images themselves, especially of chest radiographs, would be of value to both hospital infection control and governmental public health, especially during outbreak investigations. There is a trend to make such images directly available to physicians in hospitals through Web browser–based interfaces, and biosurveillance organizations could negotiate to obtain permission to access such systems or otherwise use this emerging capability.

When discussing data exchange with a hospital or other healthcare organization, the key questions to ask about radiology information systems are as follows: *Do you have a radiology information system that stores reports? Does it provide an outbound interface? Do you send the reports to the HL7-message router, the data warehouse, or a POC system? Do you store images digitally (and which ones), and can your physicians access images by using the Web?*

6.7. Pathology Information Systems

Pathologists examine bodily fluids, tissue specimens, and organs. Pathology information systems are more recent additions to healthcare computing because of the image-intensive nature of pathology practice (gross and microscopic examinations). Thus, market penetration is lower than that of laboratory or radiology systems. The data that may be useful for biosurveillance include both orders (for pathology tests) and their results. Access to the data in these systems is relatively difficult, as many systems function as free-standing applications used to generate printed reports. Integration with other hospital systems has not been as critical of a design factor as in the laboratory or radiology department, so biosurveillance organizations must either develop the integration functions or influence hospitals and system designers to "biosurveillance enable" these systems.

6.8. Pharmacy Information Systems

Pharmacy information systems receive and process orders for medications such as antibiotics or antidotes for toxins, which are relevant to biosurveillance because they provide indirect evidence that the patient's illness may be caused by an infectious disease and even hint at the nature of that disease. In the vast majority of hospital pharmacies, physician orders are received on paper order forms, which pharmacists transcribe into the pharmacy information system; thus, there is a delay from the time that the physician expresses his or her understanding of the clinical problem in the form of an antibiotic order to the time that information is available electronically. The reliability of the information is extremely good, however, because pharmacists use expert knowledge and contextual information (available in the orders themselves, the pharmacy information system, and sometimes from review of the patient chart or contact with the physician) to validate the order before dispensing a medication.

6.9. Order-Entry Systems

Order-entry systems are computer systems that ward clerks or clinic staff use to communicate a physician's orders electronically to the laboratory and other departments in the hospital. If an order-entry system exists, it is a single point of access for information about orders for laboratory tests and medications, as well as orders that a patient be placed under respiratory isolation. Orders also may state a patient's diagnosis in an entry entitled "admission diagnoses."

Ward clerks or clinic staffers enter orders promptly, so the information is available without time delay, except the time lag from when the clinician writes the order on a paper order form until the time when a ward clerk transcribes the order, a delay that is measured in hours at most. The reliability and accuracy of this information is high.

In less than 10% of hospitals, physicians enter orders directly into computers, eliminating the time delay and creating an opportunity for direct interaction and decision support of the clinician (Tierney et al., 1993; Bates et al., 1994; McDonald et al., 1994; Sittig and Stead, 1994; Frost and Sullivan, 2003). We discuss the potential of direct interaction with the clinician and decision support later in this chapter.

When discussing data exchange with a hospital or other healthcare organization, the key questions to ask about order-entry systems are as follows: *Do you have an order entry system? What fraction of clinicians use it, and what fraction of orders does it capture? Does it provide an outbound interface? Do you send the orders to the HL7-message router or a data warehouse?*

6.10. Point-of-Care Systems

A POC system is a hospital (or outpatient) information system that includes bedside terminals or other devices for capturing and entering data at the location where patients receive care (Shortliffe et al., 2001). Clinicians use POC systems to record directly details of patient encounters, to review information, and to order tests and other services. POC systems replace many functions of the paper chart and, in fact, are sometimes referred to as electronic medical records (although that term is used so loosely that we recommend that it is not used). Vendors sell POC systems specialized for diverse settings, including the emergency department, physician offices, hospitals, intensive care units, long-term care facilities, and home health care. POC systems even exist for prehospital care settings. Emergency medical units may use "ruggedized" handheld computers in the field.

Depending on the POC system, a clinician may enter some subset of the data listed in Table 6.1. A clinical information system that has POC functionality has the potential to become paperless as each clinician, the laboratory, and the radiology department contribute to the collection of data about a patient. Advantages of POC systems to a hospital include quicker access to clinical information, the ability to communicate orders more quickly, elimination of the difficulties involved in reading the products of poor penmanship, and the ability to harness integrated decision-support tools such as electronic formularies, drug interaction warning databases, and electronic implementations of practice guidelines.

POC systems are the future of biosurveillance. A POC system facilitates the electronic capture of key diagnostic data (and usually in a computer-interpretable form rather than English). POC systems typically include decision-support capabilities (discussed in Chapter 13) that alert clinicians to potential drug–drug interactions and even suggest diagnoses. It is possible to program the underlying computer decision-support system to notice that a patient may have pneumonia and Gram-positive rods in a blood culture (an example of automatic case finding) and alert the clinician to consider a diagnosis of inhalational anthrax (and even report this suspicion automatically to a health department). High degrees of suspicion based on regional events can also be incorporated into the computer analysis. These capabilities are the reason that POC systems with decision support are the future of biosurveillance.

At present, most estimates of the market penetration of POC systems are in the single digits. The surgeon general offices of the nation's military services, when interviewed, were not aware of wide-spread use of POC systems in military facilities; if they are deployed, such deployments may be scattered in specific facilities. The VA, on the other hand, has high level of deployment of POC systems. Reasons for low market penetration include cost and reluctance by physicians and other providers to adopt these systems. A large multihospital organization may make a strategic decision to deploy POC system. Kaiser Permanente, in California, anticipates that its facilities will be operating an integrated POC system within five years.

In the United Kingdom, by contrast, POC systems are ubiquitous (Benson, 2002). The value of these systems for public health surveillance is illustrated by the rapidity with which the United Kingdom can potentially implement an anthrax surveillance strategy. By changing the decision support logic only, once, in a central location, the ability to detect postal workers presenting with influenza-like symptoms at the time of phone or physical presentation to any primary care physician in the country will exist.

Lazarus et al. (2002) has claimed that a POC system (a commercial product Epicare; Epic Systems Corporation, Madison, Wisconsin; *http://www.epicsys.com*) can be effective for purposes of public health reporting and bioterrorism early warning even if it serves only 5% to 10% of the population in a region being monitored. More research with POC-based surveillance is required to elucidate the relationship between the completeness of sampling of a population and the size of outbreaks of different diseases that can be detected.

6.11. Patient-Care Data Warehouses

Ralph Kimball (eminent data warehouse authority) defines a data warehouse as "a copy of transaction data specifically structured for query and analysis." Large hospital systems often build or purchase data warehouses specifically to integrate data from multiple information systems and multiple hospitals to provide clinicians with a consolidated view (often via a Web interface) of patient data (Figure 6.2). We refer to such data warehouses as *patient-care data warehouses* to distinguish them from data warehouses used for business or research purposes (Shortliffe et al., 2001).

When a patient-care data warehouse exists, it represents a point of integration of data that, similar to the HL7-message router, is a leverage point for biosurveillance. Data warehouses acquire data from other systems and transform data into a common format (e.g., data type, domain, unit of measure), and load the data into special data structures tailored for the intended use. In the case of patient-care data warehouses, the data are stored in structures that support rapid retrieval of the complete medical record of a single patient.

Transformation improves the accuracy of the data by removing duplicates from data sent to the data warehouse by laboratory or other systems. This process also may translate different hospital identification codes into a single canonical form, allowing data collected by different information systems to appear the same. Transformation is extra work that a biosurveillance organization would have to do if it were to access data directly from radiology and laboratory information systems.

If a healthcare organization has a Web-based interface to a patient-care data warehouse (as in Figure 6.2), it may be possible for a health department to negotiate with the hospital to provide its epidemiologists with access to the patient data on a need-to-know basis. Moreover, the access can be integrated within the health department's biosurveillance system. Figure 6.3 shows a sequence of screens from an early version of the RODS biosurveillance system (circa 2002) in which the user notices an increase in the number of patients with chief complaints of diarrhea, drills down to a line listing of cases, and then selects a case for which he wishes to see the patient record. After asking for authentication (a password and username issued by the healthcare system), the RODS system automatically takes him to the screen shown in Figure 6.2, which is the Web-based interface to the healthcare system's patient-care data warehouse. Note that Web browsers can remember login names and passwords, so the epidemiologist only must enter these credentials the first time he accesses the system, after which the transition to the patient-care data warehouse is seamless. During the months after the anthrax postal attacks, this function was used many times to do rapid investigations of spikes in syndrome data. A user could review approximately 40 patient charts per hour in this manner, which is several of orders of magnitude faster than conventional shoe-leather methods.

The availability of patient-care data warehouses in healthcare is low to moderate at present. Note that in many healthcare systems, a patient-care data warehouse will be a component of a more comprehensive "electronic medical record" provided by a vendor. However, it likely will still have a Web-based interface that provides a consolidated view of a patient's "chart."

In theory, it should be easy for a biosurveillance organization to interface with a data warehouse, which, if it exists, may represent a single point of integration that can provide data that have already been integrated and transformed. The key questions to ask when discussing data exchange with a hospital are as follows: *Do you have a data warehouse? Is it for clinical care or archiving and business analysis? Is it part of a more comprehensive vendor system (and which one)?* Many data warehouses now have Web-based interfaces. Although these interfaces are now being standardized, there are two competing standards. One is being promoted by Microsoft and the other by Oracle, with other vendors lining up on either side (or even both sides). So an additional question is *Does your data warehouse support either XML/A or JOLAP?*

6.12. Patient Web Portals and Call Centers

Two additional types of information systems are beginning to appear in health care. *Call centers* are facilities that receive

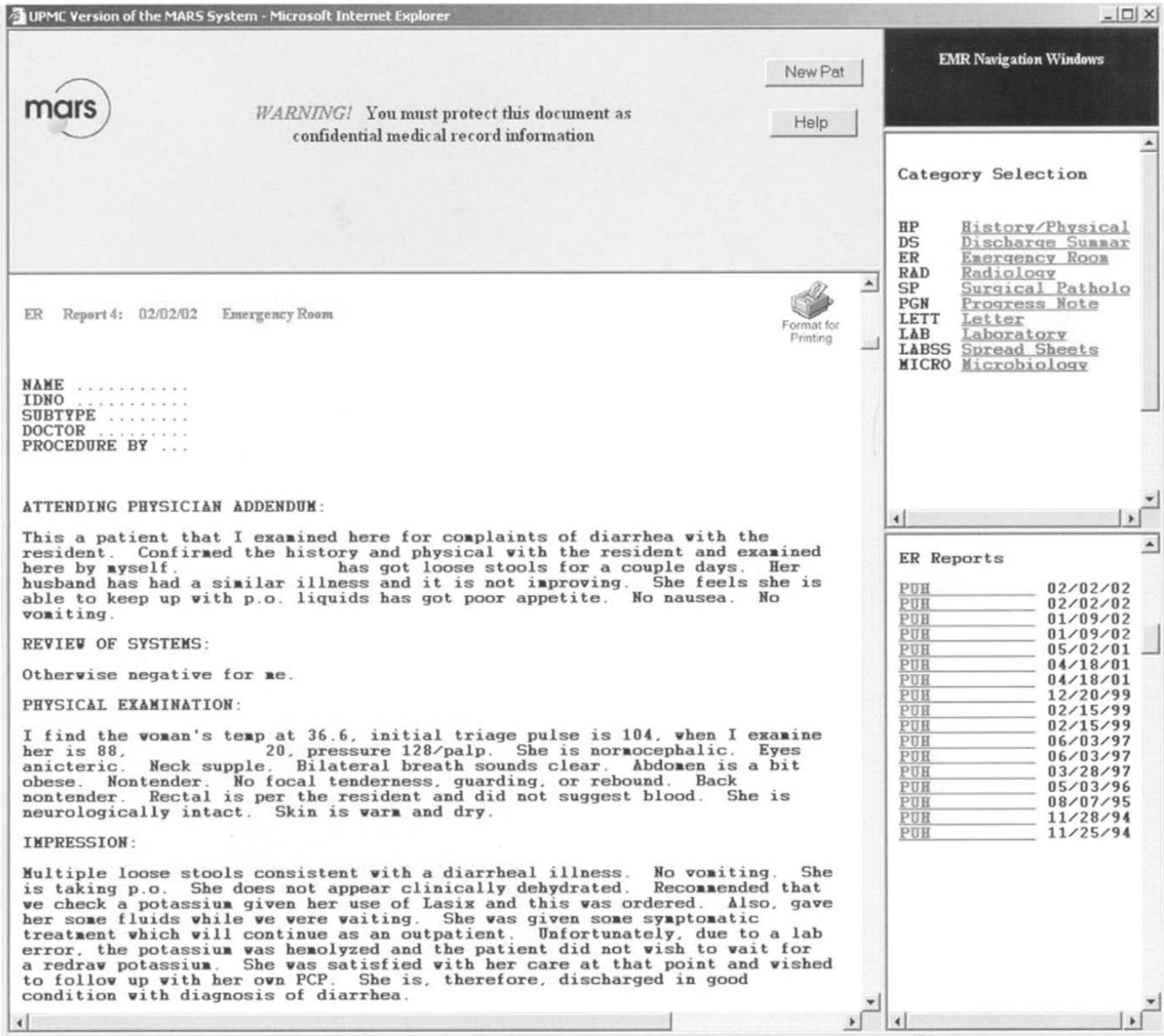

FIGURE 6.2 Web-based interface to a patient-care data warehouse. This data warehouse collects data from multiple information systems in multiple hospitals owned by the healthcare system to provide a consolidated view of a patient's medical history for a clinician. (Reproduced by permission from the University of Pittsburgh Medical Center [UPMC].)

telephone calls from sick individuals who require information, triage, appointments, or immediate assistance. The staff fielding phone calls use information systems to document the calls, typically recording diagnostic information (e.g., reason for call, symptoms, and nurse assessment). In systems for which potential use for biosurveillance has been studied (see Chapter 27), the data included the practice guideline selected by the nurse to manage the call and the reason for call with timestamps, locations, and disposition.

The most extensive use of call centers in biosurveillance is the United Kingdom's National Health Service (NHS) Direct, which is a nurse-led telephone help-line that covers the whole of England and Wales. Data on the following 10 symptoms/ syndromes are received electronically from 22 call centers and are analyzed on a daily basis; cough, cold/flu, fever, diarrhea, vomiting, eye problems, double vision, difficulty breathing, rash, and lumps. Significant statistical excesses (exceedances) in calls for any of these symptoms are automatically highlighted

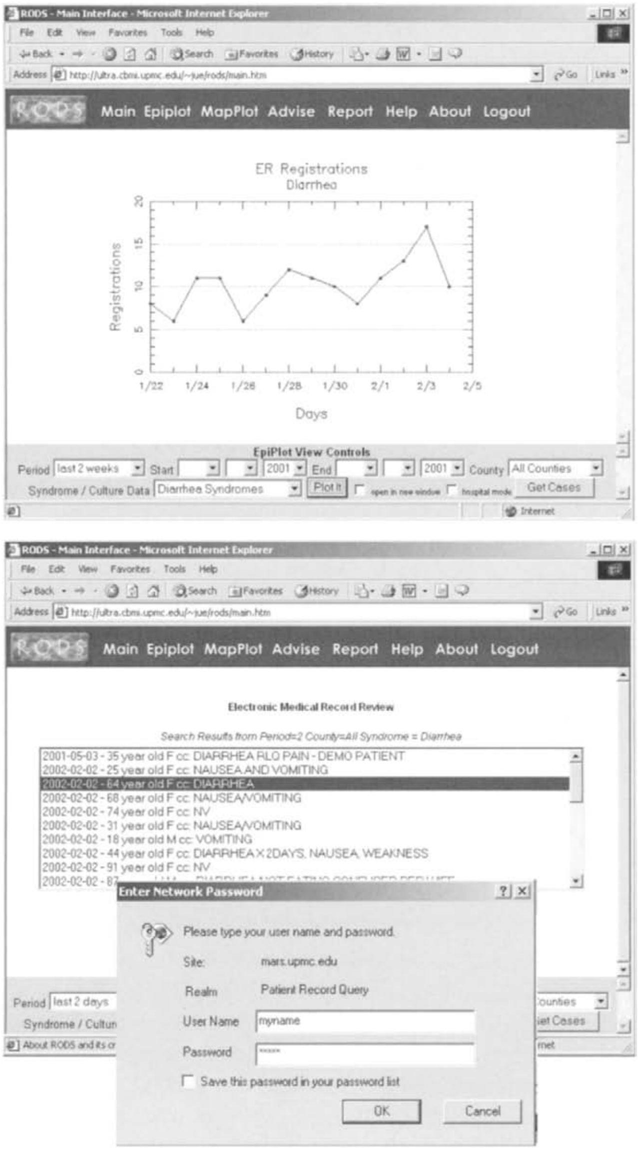

FIGURE 6.3 Sequence of screens from an early version of the RODS biosurveillance system. After noticing an increase in patients with chief complaints of diarrhea (top screen), the user drills down to a line listing of cases (bottom screen). The user selects a case to see the patient's medical record. After providing authentication (overlying dialog box), the RODS system automatically takes the user to the screen shown in Figure 6.2, which is the Web-based interface to the healthcare system's patient-care data warehouse.

and assessed by a multidisciplinary team. The aim is to identify an increase in symptoms indicative of the early stages of illness caused by the deliberate release of a biological or chemical agent, or more common infections (Harcourt et al., 2001; Cooper and Chinemana, 2004; Cooper et al., 2004a,b; Doroshenko et al., 2004; Nicoll et al., 2004).

A second large project that involves call centers is the National Bioterrorism Syndromic Surveillance Demonstration Program, coordinated by Harvard Medical School and Harvard Pilgrim Heath Care (Platt et al., 2003; Yih et al., 2004). There is no single call center for the United Sates; therefore, this project seeks to recruit and integrate the call centers for cities, regions and ultimately the entire country.

Patient Web portals provide similar functionality but are basically self-service, much like Web-based airline bookings. The types of data collected by Web portals justify their inclusion in this discussion, despite their very low market presence. Patient Web portals have the potential to collect symptom level data as early as the day of onset of illness. Call centers, if patients are encouraged to use them early rather than waiting for illness to progress, have similar potential. The reliability and availability of such data have potential to be very high, especially if such services are designed from the ground up with the needs of regional integration of data for biosurveillance purposes in mind.

7. BIOSURVEILLANCE OF THE HEALTHCARE SYSTEM

A healthcare-associated infection (HCAI) is an infection that develops in a healthcare setting such as a hospital or as a result of medical treatment. HCAIs are also known as *nosocomial infections.* HCAI is a significant problem in healthcare. In 1992, the CDC estimated that there are at least two million HCAIs in hospitalized patients alone each year in the United States, costing $4.5 billion and causing 90,000 deaths, a third of which are probably preventable (Anonymous, 1992).[5] Roughly an equal number of infections occur in long-term care facilities, dialysis centers, clinics and other settings (Martone et al., 1998).

The rate of HCAIs in hospitals has remained steady at approximately 5% of patient admissions for at least the past three decades (Haley et al., 1985a,b; Martone et al., 1998). This lack of improvement does not reflect inattention or lack of improvement in methods of prevention, but rather imperfect implementation of known measures such as hand washing, the relentless evolution of microorganisms, the severity of illness of patients, and the increasing complexity of medical treatment.

To put these statistics in perspective, Florence Nightingale, Ignaz Semmelweiss, Joseph Lister, and Oliver Wendell Holmes lived in eras in which 20% to 30% mortality from

5 These oft referenced statistics stem from data and analyses by Haley RW, Culver DH, Morgan WM, Emori TG, Munn VP, Hooton TP. *The efficacy of infection surveillance and control programs in preventing nosocomial infections in U.S. hospitals.* Am J Epidemiol 1985; 121:182-205 and Martone, W. J., Jarvis, W.R., Edwards, J.R., Culver, D.H. and Haley, R.W. (1992) In *Hospital Infections, Third Edition* (Eds, Bennett, J.V. and Brachman, P.S.) Lippincott-Raven Publishers, Philadelphia.

HCAIs was not uncommon.[6] These individuals, incidentally, pioneered methods such as hand hygiene that now form the basis of modern infection control.

Outbreaks also occur in hospitals, but they are infrequent and account for only 2% to 3.7% of HCAIs in hospitals (Wenzel et al., 1983; Haley et al., 1985b). Haley et al. (1985b) estimated that a typical community hospital has one nosocomial outbreak per year. The types of outbreaks change over time as organisms and medical technology changes. Contaminated products (e.g., blood) and medical devices are common causes of recent outbreaks investigated by the CDC (Martone et al., 1998).

7.1. Infection Surveillance Control Programs

An *infection surveillance control program* (ISCP) is a division of a healthcare organization with the mission "to identify and reduce the risks of acquiring and transmitting infections among individuals served, staff, contract service workers, volunteers, students, and visitors." (JCAHO, 2004). Among the responsibilities of an ISCP is biosurveillance of the organization.[7] In particular, an ISCP is responsible for collection, analysis and interpretation of infection control data, and the investigation and surveillance of suspected outbreaks of infection.

The origins of ISCP can be traced to a pandemic of staphylococcal infections in hospitals in the mid 1950s in the United States. In response to this problem, hospitals organized infection control committees. Over the ensuring decade, a few hospitals developed organized infection control programs, initially using physicians and then adding trained infection control nurses. By the mid 1970s, most hospitals had adopted this practice.

A typical ISCP consists of one or more doctors and nurses or medical technologists with specialized training related to epidemiology of hospital infections and disease prevention. These individuals have expertise in the recognition of disease in individual patients as well as recognition of outbreaks in the hospital population and in their prevention and control. The APIC created the Certification Board of Infection Control, which certifies infection control practitioners (Sheckler, 1998).

Approximately one-fourth to one-half of hospital HCAIs come to the attention of ISCP as a result of laboratory testing. The rest are identified by a variety of formal and informal surveillance activities. A typical ISCP identifies patients via a daily printout of "positive cultures" from an electronic laboratory system. The ISCP may also obtain a list of new prescriptions for antibiotics. A good ISCP also requires "shoe-leather" epidemiology (i.e., daily ward rounds to speak with personnel providing direct patient care) and some form of "post-discharge surveillance" to detect infections in patients who have already left the hospital. The combined result of all these processes is a list of potential patients to investigate that day. The staff reviews this list to organize and prioritize the work for the day. The staff collects additional information for each patient from hospital information systems, for example, accessing a single system or multiple systems to review radiology reports, physician dictations, medication records, and other results of laboratory testing. In addition, the staff may read the paper record of a patient or speak with physicians and nurses caring for a particular patient.

To satisfy reporting requirements, the staff may notify governmental public health when a patient with a reportable disease is found. To satisfy JCAHO requirements (discussed below), they compile periodic reports.

Prevention of infections in the healthcare setting requires cooperation of virtually all divisions and individuals. A list of related departments created by JCAHO identifies central sterile processing, environmental services, equipment maintenance personnel, facilities management (including engineering), housekeeping, information management, laboratory, medical staff, nursing, and pharmacy.

7.2. JCAHO Infection Control Guidelines

JCAHO establishes guidelines for patient safety that include guidelines for infection control. Infection control is one of JCAHO's 14 priority focus areas.

JCAHO is widely recognized for its leadership role in developing standards and performance measures and for the adaptability of its rigorous evaluation processes to emerging new forms of healthcare delivery. JCAHO evaluates and accredits more than 15,000 healthcare organizations and programs in the United States. An independent, not-for-profit organization, JCAHO is the nation's predominant

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6 Ignaz Philipp Semmelweis (1818-65), a Hungarian obstetrician, introduced antiseptic prophylaxis into medicine. In the 1840s, puerperal or childbirth fever, a bacterial infection of the female genital tract after childbirth, was taking the lives of up to 30% of women who gave birth in hospitals. Women who gave birth at home remained relatively unaffected. Semmelweis observed that women examined by student doctors who had not washed their hands after leaving the autopsy room had very high death rates. When a colleague who had received a scalpel cut died of infection, Semmelweis concluded that puerperal fever was septic and contagious. He ordered students to wash their hands with chlorinated lime before examining patients; as a result, the maternal death rate in his hospital was reduced from 12% to 1% in two years. Source: funkandwagnalls.com Copyright 1999, 2000.

7 The other responsibilities of a ISCP include (1) planning, implementation and evaluation of infection prevention and control measures; (2) education of individuals about infection risk, prevention and control; (3) development and revision of infection control policies and procedures; (4) management of infection prevention and control activities; (5) provision of consultation on infection risk assessment, prevention and control strategies. Source: *http://www.cbic.org/becoming_certified.asp.*

standards-setting and accrediting body in health care. Since 1951, JCAHO has maintained state-of-the-art standards that focus on improving the quality and safety of care provided by healthcare organizations. Infection control is a critical component of safe, quality health care.

JCAHO is becoming more active, perhaps even militant, as a result of increasing awareness of the impact of HCAIs on the cost and quality of health care. Effective January 1, 2005, JCAHO established a New Patient Safety Goal (the seventh) in the area of infection control, which it promulgates as a set of standards that includes the following: accountability of the CEO of a healthcare organization for compliance and fiscal support of an ISCP; staffing and training of ISCP; communication and coordination with health departments and other community organizations; clear command and control (delegated authority); and surveillance, and monitoring of efficacy if its infection control programs (JCAHO, 2004).

JCAHO is very influential. As previously discussed, its influence derives from the Medicare Act of 1965, which included JCAHO accreditation as one basis for Medicare reimbursement. The most recent *Accreditation Manual for Hospitals* issued by JCAHO includes a set of scoring guidelines on which the compliance of a hospital will be judged. To obtain the highest score, a hospital must provide evidence of having switched from processes such as surveillance of antibiotic use and nosocomial infections as ends in themselves to measures of patient outcomes as indicators of hospital performance. To link patient outcomes such as length of stay, days or morbidity, mortality, and costs will require substantial collection of data, or integration of data, already being collected by registration systems and billing systems.

7.3. Information Systems in Infection Control

There is and will be an increasing trend to support ISCP with IT, although the barriers to comprehensive support of all functions are high.

At present, ISCPs use computers to manage surveillance data in two ways: the most common use is to store and analyze surveillance data that are collected manually. We refer to such systems as free-standing. Far less commonly, ISCPs computerize the actual collection of surveillance data. We refer to these ISCP systems as embedded because they receive data directly from clinical information systems.

7.3.1. Free-Standing ISCP Systems

An ISCP may utilize general purpose software such as Microsoft Excel, SAS, Microsoft Access, Microsoft SQL Server, and Oracle to store and analyze surveillance data. It may use software specifically designed for infection control such as AICE, NNIS-IDEAS, QLOGIC II, Epidemic Information Exchange (Epi-X), and WHOCARE

The practice of analyzing ISCP data by using free-standing computers is nearly ubiquitous because of the low cost of computers and their ability to facilitate statistical analysis and report generation. However, ISCPs still rely heavily on paper- and card-based systems. An ISCP that collects surveillance data on paper may subsequently enter the data into a computer system simply for analytic purposes. Manual collection of data with subsequent entry into computers for storage, analysis, and report generation is by far the more common use of computers in ICSP.

7.3.2. Embedded ISCP Systems

A small but growing number of health systems have deployed embedded ISCP systems, motivated by research goals and or the potential to improve the cost-efficiency and efficacy of ICSP (although the initial cost is high).

In the 1990s, a group of researchers at the University of Utah developed a program called *Antibiotic Assistant,* which was a module in the HELP clinical information system operating at LDS hospital (Evans et al., 1985, 1986, 1992, 1998; Burke et al., 1991; Evans, 1991; Gaunt, 1991; Classen et al., 1992; Rocha et al., 1994; Chizzali-Bonfadin et al., 1995; Classen and Burke, 1995; Fiszman et al., 2000b). This research demonstrated new types of hospital infection control functionality that access to clinical information systems made possible (e.g., reminders to administer preoperative antibiotics) as well as their efficacy. An offshoot of this research was Theradoc, Inc., which has commercialized this technology.

Also in the 1990s, researchers at Barnes Jewish Christian (BJC) Hospital in St. Louis developed the GermWatch and GermAlert systems (Kahn et al., 1993, 1995, 1996a,b). Similar to Antibiotic Assistant, these systems collect surveillance data automatically from clinical information systems. They use a rule-based expert system (see Chapter 13) to detect patients of interest to ISCP. These systems are still in use at BJC Health System.

Brossette and colleagues explored the use of computers to perform brute-force search through routinely collected data (also known as data mining) to detect changes in rates of infection in subpopulations (e.g., patients in intensive care units) (Brossette et al., 1998; Moser et al., 1999; Brossette et al., 2000). An offshoot of this research was MedMined, Inc., which has commercialized this technology.

Although the above systems have demonstrated the feasibility of automatic data collection, their market penetration remains low owing to their cost and lack of definitive economic data showing direct benefit to healthcare systems.

7.4. Challenges to Automating ISCP

The challenges to integrating patient data for biosurveillance in the hospital are identical or greater than are those for integrating biosurveillance data for public health surveillance. The difficulty is slightly greater because the set of diseases of concern in ISCP are a superset of those of concern in public health practice. Not only must the healthcare system report notifiable conditions to governmental public health, but it is encouraged by JCAHO to monitor for urinary tract infections, pneumonia, multiple drug-resistant organisms (e.g., methicillin-resistant *Staphylococcus aureus* and vancomycin resistant *enterococci*), surgical site infections, infections related to implanted devices, needle-stick injuries in staff, and infections within immunocompromised patient populations. JCAHO also encourages healthcare organizations to monitor health outcomes in addition to infection control processes. To automate this type of analysis, an organization must integrate data about processes (e.g., which surgeon performed which procedure on which patient on which date) with data about outcomes (e.g., infection rate, length of stay, and hospital costs).

There are healthcare systems that have accomplished such integration. However, they are the exception rather than the rule. These healthcare systems had already achieved a high level of information system integration for other reasons. They had sufficient medical informatics expertise and grant funding to integrate the systems. They are to some degree the same organizations that we discuss in the next section on regional health information organizations (RHIOs). This overlap is not coincidental. The same IT infrastructure that is a prerequisite for automated sharing of clinical information among hospitals is required for automation of hospital infection control.

7.5. Hospital Biosurveillance as a Model of an Ideal Biosurveillance System

It is interesting to note that biosurveillance in hospitals is more intensive than in the general population. In fact, many of the ingredients of an ideal biosurveillance system (see Chapter 13) are already in place in modern hospitals: highly trained clinicians evaluate every patient every day, patient's temperatures are taken regularly, and surveillance data are available electronically in real time. The few missing ingredients include surveillance of the staff and visitors (who are part of the population) and real-time information about patterns of disease in the community, including other hospitals and long-term care facilities from which patients are transferred. Nevertheless, the ideal biosurveillance system that we will discuss in Chapter 13 has its most complete realization in the modern hospital.

8. ASPs AND RHIOs

Two important trends in clinical computing are (1) the use of application service providers (ASPs), and (2) regional integration of healthcare data for the improvement of clinical care.

8.1. Application Service Providers

ASPs are companies that are in the business of hosting computer applications in central locations. A healthcare system may contract with an ASP to outsource some or all of its data processing. Clinicians interact with the server-based applications over private or public networks. The relevance of an ASP for regional or national biosurveillance is that an ASP may, after obtaining appropriate legal and administrative permission, provide data collected by many healthcare systems. The physical colocation of hundreds of clinical information systems in a single location is helpful but it represents a 20% solution, with the residual 80% comprising unaddressed confidentiality, organizational, vocabulary, and other data integration issues.

8.2. National Health Information Infrastructure

The NHII is an initiative of the U.S. government whose goal is to promote the use of IT by the healthcare system. The government, in particular, hopes to improve the quality of medical care while also reducing its cost.[8]

Importantly, NHII understands the importance of biosurveillance (National Committee on Vital and Health Statistics, 2001, Thompson and Brailer, 2004). The objectives of NHII relevant to biosurveillance are (1) increasing the adoption of electronic medical records, (2) promoting the exchange of data among various healthcare organizations, and (3) improving public health (Thompson and Brailer, 2004).

8.2.1. Increasing Adoption of Electronic Medical Records

The relevance of the first objective to biosurveillance is that data that currently exist only on paper would become available electronically. The federal government, as part of its NHII initiative, has taken several actions to promote adoption of electronic medical records.

The Center for Medicare and Medicaid Services (CMS) announced in July 2005 that it will make available to physicians a free electronic medical record called Office-VistA, which is based on the electronic medical record, VistA, used by VA hospitals throughout the United States. Because the VA also provides outpatient care in clinics located in its facilities, VistA has significant functionality for outpatient offices. CMS is working with the VA to create Office-VistA from VistA by removing inpatient functionality and making it easy to install.

In 2004, CMS initiated a pilot program called Doctor's Office Quality (DOQ)-IT.[9] As part of the DOQ-IT pilot, four Quality Improvement Organizations (QIO)[10] in four states received contracts to assist physicians with selecting and implementing EMRs. Based on the pilot, CMS has subsequently funded the QIO in every state to assist physicians with adoption of EMRs, with the sum of all QIO contracts totaling $120 million (Monegain, 2005).

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8 Similar initiatives exist in other countries, inculding the United Kingdom, Australia, and Canada.

9 *See http://www.doqit.org*

10 The Peer Review Improvement Act of 1982 created Quality Improvement Organizations to improve the quality of care received by Medicine beneficiaries, ensure that beneficiaries receive only medically necessary care, and handle individual beneficiary issues such as complaints about care received.

In 2004, the Secretary of Health and Human Services (HHS) created an exception to the Stark law for the development of a "community-wide health information system." The Stark law is a federal statute that prohibits physicians from referring Medicare patients to a facility with which they have a financial relationship.[11] It has been an obstacle for hospitals that wished to provide associated outpatient practices with EMRs because providing a practice with an EMR creates a financial relationship under the law. However, the Stark law includes a provision that permits the Secretary of HHS to exempt a specific financial relationship if he or she determines that the relationship does not pose a risk for abuse. Thus, the Secretary of HHS in 2004 made an exception for provision of an EMR when the EMR is necessary to connect to a community-wide health information system.[12] This action by the Secretary of HHS may encourage the development of community-wide efforts to exchange patient data from the outpatient setting and the provision of EMRs to physicians by organizations that participate in the community-wide effort.[13] We discuss some of these community-wide efforts next.

8.2.2. Promoting Exchange of Healthcare Data

Central to the NHII effort is the concept of a *RHIO*.[14] A RHIO is typically a nonprofit organization founded by a multistakeholder group in a single metropolitan region or state. Its mission is typically to develop electronic exchange of patient data (both clinical and administrative) among its member organizations. The NHII concept also includes inter-RHIO data exchange so that when patients travel or move from one region to another, their medical records are available to treating physicians and other authorized parties.

The organizations that participate in a RHIO vary, but most often they include health plans, hospitals, and physicians. Other organizations that participate less frequently include pharmacies, commercial laboratories, diagnostic imaging centers, nursing homes, and government agencies such as health departments.

The RHIO movement can be traced to the Community Health Information Network (CHIN) movement that began and largely ended in the first half of the 1990s. CHINs had similar goals as today's RHIOs: electronic exchange of health care data to support patient care. The CHIN movement largely collapsed because of lack of trust among competing organizations, concerns about privacy of data, failure of the technological approach of creating a centralized database, and the cost of technology at that time (Appleby, 1995; Starr, 1997; Payton and Ginzberg, 2001; MacDonald and Metzger, 2004).

The RHIO movement has better prospects for success because the federal government is providing incentives and addressing the aforementioned problems that CHINs encountered. At present, federal incentives to RHIOs have mostly come in the form of grant funding. The Agency for Healthcare Research and Quality (AHRQ) has provided nearly $150 million in grant funding to support healthcare data exchange. Federal efforts also include promoting healthcare IT standards (for details on federal efforts to promote the creation and adoption of IT standards necessary for data exchange, see Chapter 32).

The RHIO movement is in its infancy. Overhage et al. (2005) report the results of a recent survey of RHIOs that identified only nine operational RHIOs out of 134 that responded. A majority of RHIOs that provided information to the survey did not yet have substantial commitment from the leadership of the various organizations involved. Nearly one-third of these RHIOs had no funding. The most common technological approach was a centralized database, which was a cause of failure during the CHIN movement (MacDonald and Metzger, 2004). The report notes that a federated database is a characteristic of successful RHIOs.[15] The report judged the RHIOs' plans for implementing data exchange as overly ambitious in general.

Table 6.3 summarizes states in which a single RHIO is attempting to integrate clinical data across a whole state. These statewide RHIOs are also in a state of infancy, with only four of the RHIOs actively exchanging data (three are exchanging clinical data). Two-thirds of the RHIOs are new, having formed only in the past two years.

11 The rationale for this law is that physicians might refer patients to facilities with which they have a financial relationship (such as an ownership relationship) even when it is not in the best interest of the patient.

12 There are other qualifications on the exception, such as the community-wide health information system must be available to all physicians who wish to participate, the party providing the EMR cannot take referrals into account when deciding which physicians to give an EMR, and the arrangement cannot violate the Anti-Kickback Law (another law that regulates hospital-physician relationships).

13 Many observers have noted that this exception, although important, may not be sufficient to spur the provision of EMRs to physicians because it does not define "community-wide health information system" or change the Anti-Kickback Law, which is another legal barrier to hospitals providing physicians with EMRs.

14 Also known as a local or regional health information infrastructure.

15 A centralized database is a single collection of patient data from all the healthcare organizations in the community. A federated database, on the other hand, is a system of sending data about patients from one organization to another only when there is a legitimate request.

TABLE 6.3 Regional Healthcare Organizations

Year	State	RHIO	Admin*	Clinical†	Govern‡	Funded§
1993	Utah	Utah Health Information Network	X			X
1993	Wisconsin	Wisconsin Health Information Network	X	X		
1996	Indiana	Indiana Health Information Exchange	X	X		X
1997	Delaware	Delaware Health Information Network			X	
2003	Massachusetts	Massachusetts SHARE (Simplifying Healthcare Among Regional Entities)	X	X		X
2004	Colorado	Colorado Health Information Exchange				X
2004	Florida	Florida Health Information Infrastructure			X	
2004	Minnesota	Minnesota eHealth Initiative			X	
2004	Rhode Island	Rhode Island Health Improvement Initiative			X	X
2004	Tennessee	Volunteer eHealth Initiative			X	X
2005	Pennsylvania	Pennsylvania eHealth Initiative				
2005	Wyoming	WyHIO			X	

RHIO indicates regional health information organization.
*RHIO is exchanging administrative and billing data.
†RHIO is exchanging clinical data.
‡The state government played a major role in creation of RHIO; either through legislation that created the RHIO or through a government agency that convened the stakeholders.
§RHIO has received external funding as of this writing.

We next discuss three of the most well-known RHIOs (two of which are statewide) and use these examples to explore the opportunities and challenges inherent in the NHII effort.

The Indiana Health Information Exchange (IHIE) is arguably the most successful RHIO to date. IHIE was formed in 1996 as the Indianapolis Network for Patient Care when Wishard Memorial Hospital began sharing its data unilaterally with other hospitals to demonstrate the value of health-data exchange. As a result of this leadership, other organizations began sharing their data, and by 2004, the RHIO included five healthcare systems (14 hospitals total), four homeless clinics, and three hospital-affiliated physician group practices. In 2004, the scope of the RHIO expanded to statewide.

The IHIE illustrates the promise that NHII holds for biosurveillance. By 2001, IHIE was reporting notifiable diseases over a single network connection to the Marion County Health Department[16] from five clinical laboratories serving nine hospitals (Overhage et al., 2001). The IHIE had already standardized its participating laboratories' data for purposes of clinical data exchange before the biosurveillance project. It therefore reports notifiable diseases to Marion County Department of Health by using current CDC-recommended standards (HL7, LOINC, and SNOMED). As the IHIE expands and standardizes the laboratory data for additional hospitals in Indiana, the data will be available for biosurveillance as a by-product of what is fundamentally a clinical data integration project. At present, the IHIE also reports chief complaint data for biosurveillance over a single connection from all the participating hospitals.

The IHIE also illustrates the challenge of NHII. It took several years for IHIE to create the administrative and technical infrastructure necessary to integrate data from just nine laboratories. IHIE had to obtain sufficient grant funding to develop the data systems and manage the project, and the technical staff had to analyze the laboratory data and develop custom software to translate the data into standard encodings and formats. We note that the required skill set for understanding laboratory information management system data and creating translation capability is not widely available. Finally, the IHIE (as with other RHIOs) still has not achieved a business model that allows it to be self-sufficient without grant support.

The Santa Barbara County Care Data Exchange was founded in 1998 and incorporated in 1999. Its participating organizations planned to start exchanging data only in February 2005 (Anonymous, 2005). This RHIO is noteworthy for being a case study in the cost and effort to develop a RHIO. It has already spent $10 million in grant funding from the California Health Care Foundation to develop the organizational and technical infrastructure necessary for data exchange, and in 2004, it received another $400,000 in funding from the federal government (Colliver, 2005). We note that this cost and effort does not include the cost of data standardization.[17] Furthermore, data do not flow from one organization's information system to another, but instead physicians view all the data for a

16 The city of Indianapolis, IN is located in Marion Country.

17 The Santa Barbara Country Care Data Exchange makes use of HL17 Clinical Context Object Workgroup standard. However, this standard is not a data standard, but a standard way of passing patient and user informatin among clinical applications so that viewing a patient's data that resides in one application while using another application is seamless. The data viewed, however, may be (and often are) nonstandard.

patient—regardless of the organization at which the data originated—by using a Web browser.

The Utah Health Information Network (UHIN) was founded in 1993. At present, the participating organizations are hospitals, physicians, and every health plan in Utah except one. These organizations exchange administrative and billing data. By use of an AHRQ grant of $5 million awarded in 2004, it has recently begun the work to exchange clinical data among its member organizations. UHIN also illustrates the difficulty of NHII: in its 12 years of existence, it has accomplished the exchange of only nonclinical, administrative data among many, but not all health plans, hospitals, and physicians in Utah.

8.2.3. Improve Public Health

As the first two NHII goals are achieved, regional healthcare data will become increasingly available for biosurveillance. RHIOs will provide increasing coverage of the relevant organizations in a region. Instead of having to establish point-to-point data exchange with dozens of hospitals, hundreds or thousands of physicians, and numerous laboratories, pharmacies, and diagnostic imaging centers, a biosurveillance organization will establish a single relationship and technical connection to a RHIO. It is perhaps obvious, but worth stating, that ensuring that RHIOs are designed to meet the needs of biosurveillance will increase their societal value and potentially lower costs for all parties involved in the RHIO by expanding the set of organizations that might share in the development and operational costs.

8.2.4. Is the Glass Half Empty or Half Full?

Despite the current momentum of the NHII initiative, we caution that many barriers to progress exist. A recent study by Kaushal et al. (2005) suggests that the 5-year cost to achieve a model National Health Information Network[18] exceeds projected spending on IT by the healthcare system.

Even if the U.S. Congress was to authorize the additional $132 billion estimated by Kaushall et al. to create an *achievable* (as opposed to ideal) model NHII, the number of technicians required for tasks such as vocabulary mapping and system integration is likely to be rate limiting. Governmental public health departments continue to expend resources on alternative solutions such as Web-based disease reporting and direct ELR, which consumes healthcare resources. Healthcare systems have finite resources and devoting them to one project often comes at the cost of not being able to devote them to another project. The CDC has advocated for NHII but has not yet invested in its development or included it in guidelines that shape how state and local departments of health invest federal funds.

Nevertheless, the potential advantages of the NHII model and its current momentum suggest that NHII will transform significantly how the United States conducts biosurveillance in the future.

9. BARRIERS TO TIGHTER INTEGRATION BETWEEN HEALTH CARE AND GOVERNMENTAL PUBLIC HEALTH

Because of the importance of the healthcare system for the biosurveillance conducted by governmental public health, it is worth considering here, at the end of two chapters, these two pillars of biosurveillance and the current status of their integration.

Ideally, the two domains would exchange relevant data bidirectionally and in real time. The healthcare system would transmit data needed for outbreak detection, characterization, and management (e.g., bed status, treatment status of victims) to governmental public health. Governmental pubic health would transmit data needed by clinicians for case detection (e.g., case definitions and up-to-the-minute information about population health relevant to diagnosis of individual patients) to the healthcare system. The data exchanges would be secure and satisfy the ethical requirement of "minimal need to know" and a patient's rights to confidentiality.

In addition, the workflow processes related to detection and characterization of outbreaks would be distributed optimally across both domains to maximize the efficiency and speed of the biosurveillance process. Most clinicians are capable, for example, of making observations needed to complete a case-investigation form, but at present this is a task conducted by a health department. Considerable efficiency and speed-up may be possible if IT were to enable a physician to elicit and record more epidemiologically relevant data about a patient with hepatitis A at the time the patient presents in the office setting. This level of integration is many years in the future and requires a rethinking of current systems that takes into account the potential of IT to enable conceivable, but previously impossible, configurations of organizations and workflows.

The need for such integration has been understood for many years, and widely accepted since the anthrax postal attacks of 2001. That such integration is feasible technically has been proven beyond the shadow of doubt by the success of the IHIE and other RHIOs. It is therefore reasonable to ask whether the progress has been satisfactory, given the resources that have been devoted to the problem. Has the progress been exemplary, the best achievable, or less?

18 They define an achievable National Health Information Network as an information system that enables physicians to review the results of testing done in both an inpatient and outpatient setting, review and update both inpatient and outpatient medical records, order treatments including medications, verify the eligibility of patients for various services under their health insurance plans, communicate with patients securely (for example, secure email), and transmit prescriptions electronically to pharmacies.

The current status, four years after October 4, 2001 (the date of public awareness of the first case of inhalational anthrax from contaminated mail), is that the healthcare system by and large continues to report notifiable diseases to governmental public health by using forms that must be completed manually. There is an increasing trend toward the forms being online, but the workflow process for the reporting clinician is otherwise unchanged. There are many syndromic surveillance projects in which the healthcare system sends minute quantities of data (de-identified ED registration records) to health departments. A handful of the more than 5,000 hospitals in the United States send laboratory data electronically to governmental public health.

Earlier in this chapter, we identified barriers that in part explain the gap between what is and what could be. They include the recording of data on paper only (especially in outpatient settings), the sheer number of hospitals, the numerous departmental information systems within each hospital, nonstandard data formats, and the low market penetration of the types of information systems of most value.

It may be instructive to examine just the integration that should exist between laboratory information management systems and governmental public health. As we discuss in Chapter 8, laboratory test orders and results are highly automated in most hospitals. There are many firms that are in the business of creating interfaces between laboratory information systems and other information systems in hospitals. Although it is true that significant effort is required to create an interface, the effort is finite and the cost is in the neighborhood of $100,000 (Overhage et al., 2001) for a comprehensive interface (one that covers all laboratory tests). The cost would likely be lower for an interface that covered only results of interest to biosurveillance. Even were the cost to be as high as $100,000, the total cost for 10,000 interfaces (more than the number of hospitals in the United States) would be $1 billion dollars. One of the authors in fact presented this option to President Bush in February 2002. The President's DHHS advisor quickly interjected that DHHS already had a plan to send $1 billion to the states to address the problem of bioterrorism. Since then, the federal government has provided several billion dollars to the states for bioterrorism preparedness.

This example suggests that an additional barrier at present may be the direction that the government is taking. As discussed in Chapter 5, the government because of its power to tax and enact law, is essential to the creation of systems for the public's good. Such systems cannot come into being without the leadership of a government. However, the leadership must lead in the right direction.

The idea that governmental public health should provide the leadership for the integration of the healthcare system for biosurveillance may be a barrier to progress. Governmental public health organizations have different priorities at present. Their biosurveillance priority, and perhaps rightly so, is to integrate their own systems and to connect to other governmental public health organizations and governmental laboratories so that they can manage outbreaks. Their evolving plan for integrating the healthcare system at present is to connect each hospital electronically to a health department and to leverage RHIOs should they exist. The CDC is also advocating a plan to connect hospitals directly to the CDC and then route the data to health departments.

This may be the wrong idea for biosurveillance. An alternative approach would be for every hospital and healthcare provider in a region to link with each other (the RHIO model) and then create a single connection from the RHIO to governmental public health. The oldest RHIOs have been in existence for more than a decade and have solved many technical and administrative barriers to regional exchange of data. The healthcare and pharmacy organizations within the regions have far more technical capability to create such connections than does a health department. As nongovernmental organizations, they have more flexibility and in some cases more resources.

A key advantage to the RHIO model is that it avoids the construction of two separate but redundant infrastructures: one for public health purposes and one for clinical care. The alternative model of governmental public health creating a separate biosurveillance infrastructure misses the opportunity for a dual-purpose system, which would also be more mission critical to the healthcare system and therefore promoted to a higher priority for both development and long-term maintenance.

10. SUMMARY

Clinical data collected by the healthcare system are a rich source of data for biosurveillance. They include the data needed for earlier detection of cases and outbreaks and for more rapid characterization of outbreaks. Clinical data in the United States at present, however, are not highly available for biosurveillance (other than that practiced by hospital infection control). The barriers include the use of paper records, multiple departmental information systems, and nonstandard data formats. In countries with national health systems such as the United Kingdom, these barriers are less daunting.

The types of data that are available in electronic form in the United States are weighted toward data collected for administrative purposes such as patient registration and billing (and market penetration is high for such systems). Some administrative systems—registration, scheduling, and billing—have data that are of value for biosurveillance and developers of new strategies for early detection of outbreaks are using these data. The use of computers to record clinical information has lagged administrative use, and market penetration is variable depending on the type of system. Clinical information systems are widely deployed in clinical laboratories and radiology departments, and are less used in pathology departments and as POC systems. Specific data that are highly available, although difficult to access, include laboratory and radiology results.

Key gaps are symptom and sign data, which are often recorded by using English, not computer encoding. The market penetration of IT into small private practices is less than in large practices; even when small practices use IT, the sheet numbers of such practices make integration of their data into a biosurveillance network an expensive and time-consuming project.

A bright note is that the clinical computing industry has been working on the problem of interfacing and data integration for several decades, so there is a large body of work already completed toward solutions that can be applied directly to the problem of integrating clinical data into biosurveillance.

A biosurveillance organization such as a state health department that wishes to create real-time data exchange with a hospital should develop both a short-term and a long-term strategic plan. In the short term, it should work with each hospital organization to determine whether the appropriate technical approach to data exchange should focus on building an interface to an existing HL7-message router, an interface to an existing data warehouse, or a POC system (or systems). We discussed principles to guide such decisions.

In the long-term, the health department should factor two megatrends into its planning. The first is that POC systems will become commonplace in both the outpatient and inpatient settings. Unless these systems are *biosurveillance-enabled,* meaning that their manufacturers engineer these systems to be able to interoperate with biosurveillance organizations, additional work will have to be done to create such interfaces. The second is the NHII movement, which, if supported by governmental public health, may lead to the required biosurveillance enabling of clinical information systems on an accelerated time frame.

The protestant minister, when asked for his secret for giving a good sermon, responded "first I tell them what I'm gonna tell them, then I tell them, then I tell them what I told them." POC systems with decision support are the future of biosurveillance. HL7-message routers represent unique resources for the present. POC systems enable collection of symptom and sign data in coded format. Their decision support capabilities can support real-time bidirectional interactions among frontline clinicians and biosurveillance organizations. They can support computer-based case detection and case reporting. The RHIO component of the NHII movement is also important, if it is supported, to the future of biosurveillance. POC systems with decision support and RHIOs are important to the future of biosurveillance.

ADDITIONAL RESOURCES

Clinical Information Systems

Shortliffe, E.H., et al., eds. (2001). *Medical Informatics: Computer Applications in Health Care and Biomedicine.* New York: Springer. Chapters 9, 10, and 12 discuss computer-based patient record systems.

Infection Control

Journals

American Journal of Infection Control
Infection Control & Hospital Epidemiology
Morbidity and Mortality Weekly Report, CDC

Guidelines and Standards

Joint Commission on the Accreditation of Healthcare Organizations (JCAHO), including *Meeting JCAHO's Infection Control Requirements* (2004)

Occupational Health and Safety Administration (OSHA)

American Hospital Association (AHA). Position papers and guidelines.

Association for Professionals in Infection Control and Epidemiology (APIC). Guidelines on infection control

Books

Association for Professionals in Infection. (2002). *APIC Handbook of Infection Control*, 3rd ed. Washington, DC: Association for Professionals in Infection.

Association for Professionals in Infection. (2005). *APIC Text of Infection Control and Epidemiology.* Washington, DC: Association for Professionals in Infection.

Bennett, J. and Brachman, P., eds. (1998). *Hospital Infections.* Philadelphia: Lippincott-Raven Publishers. A textbook on hospital epidemiology.

Mandell, G.L., Bennett, J.E., and Dolin, R. (2003). 2003 Red Book: Report of the Committee on Infectious Diseases, 26th ed. American Academy of Pediatrics.

Wenzel, R.P. ed. (2002). *Prevention and Control of Nosocomial Infections,* 4th ed. New York: Lippincott Williams & Wilkins

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REFERENCES

Anonymous. (1992). Public Health Focus: Surveillance, Prevention, and Control of Nosocomial Infections. *Morbidity and Mortality Weekly Report* vol. 41:783–787.

Anonymous. (2005). Santa Barbara County Care Data Exchange and CareScience Announce Next Step in Roll-out of Care Data Exchange Solution. *Business Wire* February 14.

Appleby, C. (1995). The trouble with CHINS (Community Health Information Networks). *Hospital Health Networks* vol. 69:42–44. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=7728164.*

Bates, D.W., Boyle, D.L., and Teich, J.M. (1994). Impact of Computerized Physician Order Entry on Physician Time. *Proceedings of the Annual Symposium on Computer Applications in Medical Care* 996.

Benson, T. (2002). Why General Practitioners Use Computers and Hospital Doctors Do Not, Part 1: Incentives. *British Medical Journal* vol. 325:1086–1089.

Brossette, S.E., Sprague, A.P., Hardin, J.M., Waites, K.B., Jones, W.T., and Moser, S.A. (1998). Association Rules and Data Mining in Hospital Infection Control and Public Health Surveillance. *Journal of the American Medical Informatics Association* vol. 5:373–381.

Brossette, S.E., Sprague, A.P., Jones, W.T., and Moser, S.A. (2000). A Data Mining System for Infection Control Surveillance. *Methods of Information in Medicine* vol. 39:303–310.

Burke, J.P., Classen, D.C., Pestotnik, S.L., Evans, R.S., and Stevens, L.E. (1991). The HELP System and Its Application to Infection Control. *Journal of Hospital Infection* vol. 18:424–431.

Certification Board of Infection Control and Epidemiology. (2005). Becoming Certified. *http://www.cbic.org/Becoming_Certified.asp.*

Chapman, W. and Haug, P. (1999). Comparing Expert Systems for Identifying Chest X-Ray Reports that Support Pneumonia. *Proceedings of AMIA Annual Symposium* 216–220.

Chizzali-Bonfadin, C., Adlassnig, K.P., and Koller, W. (1995). MONI: An Intelligent Database and Monitoring System for Surveillance Of Nosocomial Infections. *Medinfo* vol. 8:1684.

Classen, D.C. and Burke, J.P. (1995). The Computer-based Patient Record: The Role of the Hospital Epidemiologist. *Infection Control and Hospital Epidemiology* vol. 16:729–736.

Classen, D.C., Evans, R.S., Pestotnik, S.L., Horn, S.D., Menlove, R.L., and Burke, J.P. (1992). The Timing of Prophylactic Administration of Antibiotics and the Risk of Surgical-Wound Infection. *New England Journal of Medicine* vol. 326:281–286.

Colliver, V. (2005). Medical Data Made Whole: Health Exchanges Hope To Offer All Patient Records in One Place. *San Francisco Chronicle* March 8.

Cooper, D. and Chinemana, F. (2004). NHS Direct Derived Data: An Exciting New Opportunity or an Epidemiological Headache? *Journal of Public Health* vol. 26:158–160.

Cooper, D., et al. (2004a). Can We Use Self-Testing To Augment Syndromic Surveillance? A Pilot Study Using Influenza. *Morbidity and Mortality Weekly Report* (Submitted).

Cooper, D., et al. (2004b). A national symptom surveillance system in the UK using calls to a telephone health advice service. *Morbidity and Mortality Weekly Report* vol. 53 (Suppl):179–83.

Department of Health and Human Services. (2002). Medical Privacy: National Standards to Protect the Privacy of Personal Health Information. *http://www.hhs.gov/ocr/hipaa/finalreg.html.*

Doroshenko, A., Cooper, D., Smith, G., Gerard, E., Chinemana, F., and Verlander, N. (2004). Evaluation of Syndromic Surveillance Based on NHS Direct Derived Data in England and Wales. *Morbidity and Mortality Weekly Report* (Submitted).

Effler, P., Ching-Lee, M., Bogard, A., Man-Cheng, L., Nekomoto, T., and Jernigan, D. (1999). Statewide System of Electronic Notifiable Disease Reporting from Clinical Laboratories: Comparing Automated Reporting with Conventional Methods. *Journal of the American Medical Association* vol. 282:1845–1850.

Espino, J. and Wagner, M. (2001). The Cccuracy of ICD-9 Coded Chief Complaints for Detection of Acute Respiratory Illness. *JAMIA Symposium Issue.*

Evans, R.S. (1991). The HELP System: A Review of Clinical Applications in Infectious Diseases and Antibiotic Use. *MD Computing* vol. 8:282–288, 315.

Evans, R.S., et al. (1985). Development of a Computerized Infectious Disease Monitor (CIDM). *Computers and Biomedical Research* vol. 18:103–113.

Evans, R.S., et al. (1986). Computer Surveillance of Hospital-Acquired Infections and Antibiotic Use. *Journal of the American Medical Association* vol. 256:1007–1011.

Evans, R.S., et al. (1992). Computerized Identification of Patients at High Risk for Hospital-Acquired Infection. *American Journal of Infection Control* vol. 20:4–10.

Evans, R.S., et al. (1998). A Computer-Assisted Management Program for Antibiotics and Other Antiinfective Agents. *New England Journal of Medicine* vol. 338:232–128. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=9435330.*

Fiszman, M., Chapman, W., Aronsky, D., Evans, R., and Haug, P. (2000a). Automatic Detection of Acute Bacterial Pneumonia from Chest X-Ray Reports. *Journal of the American Medical Informatics Association* vol. 7:593–604.

Fiszman, M., Chapman, W.W., Aronsky, D., Evans, R.S., and Haug, P.J. (2000b). Automatic detection of acute bacterial pneumonia from chest X-ray reports. *Journal of American Medical Information Association* vol. 7:593–604. *http://www.jamia.org/cgi/content/full/7/6/593*

Frost & Sullivan. (2003). U.S Computerized Physician Order Entry Market, 2002. New York: Market Research. *www.marketresearch.com.*

Gaunt, P.N. (1991). Information in Infection Control. *Journal of Hospital Infection* vol. 18:397–401.

Gesteland, P.H., et al. (2002). Rapid Deployment of an Electronic Disease Surveillance System in the State of Utah for the 2002 Olympic Winter games. *Proceedings : A Conference of the American Medical Informatics Association* 285–289. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12463832.*

Gesteland, P.H., et al. (2003). Automated Syndromic Surveillance for the 2002 Winter Olympics. *Journal of the American Medical Information Association* vol. 10:547–554. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12925547.*

Haley, R.W., et al. (1985a). The Efficacy of Infection Surveillance and Control Programs in Preventing Nosocomial Infections in U.S. Hospitals. *American Journal of Epidemiology* vol. 121:182–205. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=4014115.*

Haley, R.W., Tenney, J.H., Lindsey II, J.O., Garner, J.S., and Bennett, J.V. (1985b). How Frequent Are Outbreaks of Nosocomial Infection in Community Hospitals? *Infection Control* vol. 6:233–236.

http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=3848422.

Harcourt, S., et al. (2001). Can Calls to NHS Direct Be Used for Syndromic Surveillance? A Pilot at Three Sites Using Influenza as an Example. *Communicable Disease and Public Health* vol. 4:178–182.

Hoffman, M., et al. (2003). Multijurisdictional Approach to Biosurveillance, Kansas City. *Emerging Infectious Diseases* vol. 9:1281–1286. *http://www.cdc.gov/ncidod/EID/vol9no10/03-0060.htm.*

Hripcsak, G., Kuperman, G., Friedman, C., and Heitjan, D.F. (1999). A Reliability Study for Evaluating Information Extraction from Radiology Reports. *Journal of the American Medical Information Association* vol. 6:143–150.

Jain, N.L., Knirsch, C.A., Friedman, C., and Hripcsak, G. (1996). Identification of Suspected Tuberculosis Patients Based on Natural Language Processing of Chest Radiograph Reports. *Proceedings of the AMIA Annual Fall Symposium* 542–546.

Joint Commission on Accreditation of Healthcare Organizations [JCAHO]. (2004). *Meeting JCAHO's Infection Control Requirements.* Oakbrook Terrace, IL: Joint Commission Resources, Inc.

Kahn, M.G., Steib, S.A., Fraser, V.J., and Dunagan, W.C. (1993). An Expert System for Culture-Based Infection Control Surveillance. *Proceedings of the Annual Symposium on Computer Applications in Medical Care* 171–175.

Kahn, M.G., Steib, S.A., Spitznagel, E.L., Claiborne, D.W., and Fraser, V.J. (1995). Improvement in User Performance Following Development and Routine Use of an Expert System. *Medinfo* vol. 8:1064–1067.

Kahn, M.G., Bailey, T.C., Steib, S.A., Fraser, V.J., and Dunagan, W.C. (1996a). Statistical Process Control Methods for Expert System Performance Monitoring. *Journal of the American Medical Informatics Association* vol. 3:258–269.

Kahn, M.G., Steib, S.A., Dunagan, W.C., and Fraser, V.J. (1996b). Monitoring Expert System Performance Using Continuous User Feedback. *Journal of the American Medical Informatics Association* vol. 3:216–223.

Kaushal, R., et al. (2005). The Costs of a National Health Information Network. *Annals in Internal Medicine* vol. 143: 165–173. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=16061914.*

Knirsch, C., Jain, N., Pablos-Mendez, A., Friedman, C., and Hripcsak, G. (1998). Respiratory Isolation of Tuberculosis Patients Using Clinical Guidelines and an Automated Clinical Decision Support System. *Infection Control and Hospital Epidemiology* vol. 19:94–100.

Lazarus, R., et al. (2002). Use of Automated Ambulatory-Care Encounter Records for Detection of Acute Illness Clusters, Including Potential Bioterrorism Events. *Emerging Infectious Diseases* vol. 8:753–760. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12141958.*

Lober, W.B., Trigg, L.J., Bliss, D., and Brinkley, J.M. (2001). IML: An Image Markup Language. *Proceedings of a conference of the American Medical Informatics Association* 403–407. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11825219.*

MacDonald, K. and Metzger, J. (2004). *Connecting Communities: Strategies for Physician Portals and Regional Data Sharing.* New York: First Consulting Group.

Martone, W.J., Jarvis, W.R., Edwards, J.R., Culver, D.H., and Haley, R.W. (1992) In *Hospital Infections,* 3rd ed. (J.V Bennett and P.S. Brachman, eds.). Philadelpha: Lippincott-Raven Publishers.

Martone, W.J., Jarvis, W.R., Edwards, J.R., Culver, D.H., and Haley, R.W. (1998). Incidence and Nature of Endemic and Epidemic Nosocomial Infections. In *Hospital Infections,* 4th ed. (J.V. Bennett and P.S. Brachman, eds.). Philadelphia: Lippincott-Raven Publishers.

McDonald, C.J., et al. (1994). The Regenstrief Medical Record System: Experience with MD Order Entry and Community-wide Wxtensions. *Proceedings of the Annual Symposium on Computer Applications in Medical Care* 1059.

Monegain, B. (2005). Doctors' Offices Get Ready for Technology Makeovers. *http://www.healthcareitnews.com/NewsArticleView.aspx?ContentTypeID=3&ContentID=3214&Term=doq-it.*

Moser, S.A., Jones, W.T., and Brossette, S.E. (1999). Application of Data Mining to Intensive Care Unit Microbiologic Data. *Emerging Infectious Diseases* vol. 5:454–457.

National Committee on Vital and Health Statistics. (2001). Information for Health: A Strategy for Building the National Health Information Infrastructure. *http://ncvhs.hhs.gov/nhiilayo.pdf.*

Nicoll, A., Smith, G., Cooper, D., Chinemana, F., and Gerard, E. (2004). The Public Health Value of Syndromic Surveillance Data: Calls to a National Health Help-Line (NHS Direct). *European Journal of Public Health* vol. 14:69.

Overhage, J.M., Evans, L., and Marchibroda, J. (2005). Communities' Readiness for Health Information Exchange: The National Landscape in 2004. *Journal of the American Medical Information Association* vol. 12:107–112. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15561785.*

Overhage, J.M., Suico, J., and McDonald, C.J. (2001). Electronic Laboratory Reporting: Barriers, Solutions and Findings. *Journal of Public Health Management and Practice* vol. 7:60–66. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11713754.*

Payton, F.C. and Ginzberg, M.J. (2001). Interorganizational Health Care Systems Implementations: An Exploratory Study of Early Electronic Commerce Initiatives. *Health Care Management Review* vol. 26:20–32. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11293008.*

Platt, R., et al. (2003). Syndromic Surveillance Using Minimum Transfer of Identifiable Data: The Example of the National Bioterrorism Syndromic Surveillance Demonstration Program. *Journal of Urban Health* vol. 80(Suppl 1):i25–i31. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12791776.*

Rippen, H.E. and Yasnoff, W.A. (2004). Building the National Health Information Infrastructure. *Journal of AHIMA* vol. 75:20–26, quiz 29–30. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15141583.*

Rocha, B.H., Christenson, J.C., Pavia, A., Evans, R.S., and Gardner, R.M. (1994). Computerized Detection of Nosocomial Infections in Newborns. *Proceedings of the Annual Symposium on Computer Applications in Medical Care* 684–688.

Sheckler, W. (1998). The Role of Professional and Regulatory Organizations in Infection Control Programs. In *Hospital Infections,* 4th ed. (J.V. Bennett and P.S. Brachman, eds.). Philadelphia: Lippincott-Raven Publishers.

Shortliffe, E.H., Perreault, L.E., Wiederhold, G., and Fagan, L.M., eds. (2001). *Medical Informatics: Computer Applications in Health Care and Biomedicine.* New York: Springer.

Sittig, D.F. and Stead, W.W. (1994). Computer-based Physician Order Entry: The State of the Art. *Journal of the American Medical Informatics Association* vol. 1:108–123.

Starr, P. (1997). SMART Technology, Stunted Policy: Developing Health Information Networks. *Health Affairs* vol. 16:91–105. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=9141326.*

Thompson, T.G. and Brailer, D.J. (2004). The Decade of Information Technology: Delivering Consumer-Centric and Information-Rich Health Care. *http://www.os.dhhs.gov/healthit/documents/hitframework.pdf.*

Tierney, W.M., Miller, M.E., Overhage, J.M., and McDonald, C.J. (1993). Physician Inpatient Order Writing on Microcomputer Workstations: Effects on Resource Utilization. *Journal of the American Medical Association* vol. 269:379–373.

Tsui, F.C., et al. (2002). Data, Network, and Application: Technical Description of the Utah RODS Winter Olympic Biosurveillance System. *Proceedings of a conference of the American Medical Informatics Association* 815–819. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12463938.*

Tsui, F.-C., Wagner, M.M., Dato, V., and Chang, C.-C.H. (2001). Value of ICD-9-Coded Chief Complaints for Detection of Epidemics. *Proceedings of a conference of the American Medical Informatics Association* 711–715.

Wagner, M.M., et al. (2001). The Emerging Science of Very Early Detection of Disease Outbreaks. *Journal of Public Health Management Practice* vol. 7:51–59. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11710168.*

Wenzel, R.P., et al. (1983). Hospital-Acquired Infections in Intensive Care Unit Patients: An Overview with Emphasis on Epidemics. *Infection Control* vol. 4:371–375. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=6556158.*

Yasnoff, W.A., et al. (2004). A Consensus Action Agenda for Achieving the national Health Information Infrastructure. *Journal of the American Medical Information Association* vol. 11:332–338. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15187075.*

Yasnoff, W.A., Overhage, J.M., Humphreys, B.L., and LaVenture, M. (2001). A National Agenda for Public Health Informatics: Summarized Recommendations from the 2001 AMIA Spring Congress. *Journal of the American Medical Information Association* vol. 8:535–545. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11687561.*

Yih, W.K., et al. (2004). National Bioterrorism Syndromic Surveillance Demonstration Program. *Morbidity and Mortality Weekly Report* vol. 53:43–49. *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15714626.*