Electronic Health Record Systems

12

Clement J. McDonald, Paul C. Tang,
and George Hripcsak

After reading this chapter, you should know the answers to these questions:

- What is the definition of an electronic health record (EHR)?
- How does an EHR differ from the paper record?
- What are the functional components of an EHR?
- What are the benefits of an EHR?
- What are the impediments to development and use of an EHR?

12.1 What Is an Electronic Health Record?

The preceding chapters introduced the conceptual basis for the field of biomedical informatics, including the use of patient data in clinical practice and research. We now focus attention on the **patient record**, commonly referred to as the patient's chart, medical record, or health record. In this chapter, we examine the definition and use of electronic health record (EHR) systems, discuss their potential benefits and costs, and describe the remaining challenges to address in their dissemination.

12.1.1 Purpose of a Patient Record

Stanley Reiser (1991) wrote that the purpose of a patient record is "to recall observations, to inform others, to instruct students, to gain knowledge, to monitor performance, and to justify interventions." The many uses described in this statement, although diverse, have a single goal—to further the application of health sciences in ways that improve the well-being of patients, including the conduct of research and public health activities that address population health. A modern electronic health record (EHR) is designed to facilitate these uses, providing much more than a static view of events.

An **electronic health record** (**EHR**) is a repository of electronically maintained information about an individual's health status and health care, stored such that it can serve the multiple legitimate uses and users of the record. Traditionally, the patient record was a record of care provided when a patient was ill. Health care is evolving to encourage health care providers to focus on the continuum of health and health care from wellness to illness and recovery.

C.J. McDonald, MD (✉)
Office of the Director, Lister Hill National Center for Biomedical Communications, National Library of Medicine, National Institutes of Health,
8600 Rockville Pike 38a 7n707,
Bethesda 20894, MD, USA
e-mail: clemmcdonald@mail.nih.gov

P.C. Tang, MD, MS
Internal Medicine, Palo Alto Medical Foundation,
2350 W. El Camino Real, Mountain View 94040,
CA, USA
e-mail: paultang@stanford.edu

G. Hripcsak, MD, MS
Department of Biomedical Informatics, Columbia University Medical Center, 622 W 168th St, VC5,
New York 10032, NY, USA
e-mail: hripcsak@columbia.edu

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Consequently, we anticipate that eventually it will carry all of a person's health related information from all sources over their lifetime. The Department of Veterans Affairs (VA) has already committed to keeping existing patient electronic data for 75 years. In addition, the data should be stored such that different views of those data can be presented to serve the many different uses described in Chap. 2.

The term **electronic health record system** (also referred to as a computer-based patient-record system) includes the active tools that are used to manage the information, but in common use, the term EHR can refer to the entire system. EHRs include information management tools to provide clinical reminders and alerts, linkages with knowledge sources for health care decision support, and analysis of aggregate data both for care management and for research. The EHR helps the reader to organize, interpret, and react to data. Examples of tools provided in current EHRs are discussed in Sect. 12.3.

12.1.2 Ways in Which an Electronic Health Record Differs from a Paper-Based Record

Compared to the historical paper medical record, whose functionality is constrained by its recording media, and the fact that only one physical copy of it exists—the EHR is flexible and adaptable (see also Sect. 2.3 in Chap. 2). Data may be entered in one format to simplify the input process and then displayed in many different formats according to the user's needs. The entry and display of dates is illustrative. Most EHRs can accept many date formats, i.e. May 1, 1992, 1 May 92, or1/5/92, as input; store that information in one internal format, such as 1992-05-01; and display it in different formats according to local customs. The EHR can incorporate multimedia information, such as radiology images and echocardiographic video loops, which were never part of the traditional medical record. It can also analyze a patient's record, call attention to trends and dangerous conditions and suggest corrective actions much like an airplane flight control computer. EHRs can organize data about one patient to facilitate his or her care or about a population of patients to assist management decisions or answer epidemiologic questions. When considering the functions of an EHR, one must think beyond the constraints of paper records. An EHR system can capture, organize, analyze, and display patient data in many ways.

Inaccessibility is a problem with paper records. They can only be in one place and with at most one user at one point in time. In large organizations, medical record departments often would sequester the paper medical record for days after the patient's hospital discharge while the clinician completed the discharge summary and signed every form. Individual physicians may borrow records for their own administrative or research purposes, during which times the record will also be unavailable. In contrast, many users, including patients, can read the same electronic record at once. So it is never unavailable. With today's secure networks, clinicians and patients can access a patient's EHR from geographically distributed sites, such as the emergency room, their office, or their home. Such availability can also support health care continuity during disasters. Brown et al. (2007) found a "stark contrast" between the care VA versus non-VA patients obtained after Hurricane Katrina, because "VA efforts to maintain appropriate and uninterrupted care were supported by nationwide access to comprehensive electronic health record systems." While EHR systems make data more accessible to authorized users, they also provide greater control over access and enforce applicable privacy policies as required by the Health Insurance Portability and Accountability Act (HIPAA) (see Chaps. 10 and 27).

The EHR's content is more legible and better organized than the paper alternative and the computer can increase the quality of data by applying validity checks as data is being entered. The computer can reduce typographical errors through restricted input menus and spell checking. It can require data entry in specified fields, conditional on the value of other fields. For example, if the user answers yes to current smoker, the computer, guided by rules, could then ask how many packs per day smoked or how soon after awakening does the patient take their first smoke? So the

EHR not only stores data but can also conditionally enforce the capture of certain data elements. This enforcement power should be used sparingly, however. As part of the ordering process, the computer can *require* the entry of data that may not be available (e.g., the height of a patient with leg contractures), and thus prevent the clinician from completing an important order (Strom et al. 2010); and overzealous administrators can ask clinicians to answer questions that are peripheral to clinical care and slow the care process.

The degree to which a particular EHR achieves benefits depends on several factors:

Comprehensiveness of information. Does the EHR contain information about health as well as illness? Does it include information from all organizations and clinicians who participated in a patient's care? Does it cover all settings in which care was delivered (e.g., office practice, hospital)? Does it include the full spectrum of clinical data, including clinicians' notes, laboratory test results, medication details, and so on?

Duration of use and retention of data. EHRs gain value over time because they accumulate a greater proportion of the patients' medical history. A record that has accumulated patient data over 5 years will be more valuable than one that contains only the last month's records.

Degree of structure of data. Narrative notes stored in electronic health records have the advantage over their paper counterparts in that they can be searched by word, although the success of such searches is subject to the wide variations in the author's choice of medical words and abbreviations. Computer-supported decision making, clinical research, and management analysis of EHR data require structured data. One way to obtain such data is to ask the clinical user to enter information through structured forms whose fields provide dropdown menus or restrict data entry to a controlled vocabulary (see Chap. 7).

Ubiquity of access. A system that is accessible from a few sites will be less valuable than one accessible by an authorized user from anywhere (see Chap. 5).

An EHR system has some disadvantages. It requires a larger initial investment than its paper counterpart due to hardware, software, training, and support costs. Physicians and other key personnel have to take time from their work to learn how to use the system and to redesign their workflow to use the system. Although it takes time to learn how to use the system and to change workflows, clinicians increasingly recognize that EHR systems are important tools to assist in the clinical, regulatory, and business of practicing medicine.

Computer-based systems have the potential for catastrophic failures that could cause extended unavailability of patients' computer records. However, these risks can be mitigated by using fully redundant components, mirrored servers, and battery backup. Even better is to have a parallel site located remotely with **hot fail over**, which means that a failure at the primary site would not be noticed because the remote site could support users with, at most, a momentary pause. Yet, nothing provides complete protection; contingency plans must be developed for handling brief or longer computer outages. Moreover, paper records are also subject to irretrievable loss, caused by, for example, human error (e.g. misfiling), floods, or fires.

12.2 Historical Perspective

The development of automated systems was initially stimulated by regulatory and reimbursement requirements. Early health care systems focused on inpatient charge capture to meet billing requirements in a fee-for-service environment.

The Flexner report on medical education was the first formal statement made about the function and contents of the medical record (Flexner 1910). In advocating a scientific approach to medical education, the Flexner report also encouraged physicians to keep a patient-oriented medical record. Three years earlier, Dr. Henry Plummer initiated the "unit record" for the Mayo Clinic (including its St. Mary's Hospital), placing all the patient's visits and types of information in a single folder. This innovation represented the first longitudinal medical record (Melton 1996). The Presbyterian Hospital (New York) adopted the unit record for its inpatient and outpatient care in 1916, studying the effect of the unit record on length of stay and quality of care (Openchowski

1925) and writing a series of letters and books about the unit record that disseminated the approach around the nation (Lamb 1955).

The first record we could find of a computer-based medical record was a short newspaper article describing a new "electronic brain" – to replace punched and file index cards and to track hospital and medical records (Brain 1956). Early development of hospital information systems (HIS)—that used terminals rather than punched cards for data entry—emerged around 1970 at varying degrees of maturity (Lindberg 1967; Davis et al. 1968; Warner 1972; Barnett et al. 1979). Weed's problem-oriented medical record (POMR) (1968) shaped medical thinking about both manual and automated medical records. His computer-based version of the POMR employed touch screen terminals, a new programming language and networking—all radical ideas for the time (Schultz et al. 1971). In 1971, Lockheed's hospital information system (HIS) became operational at El Camino Hospital in Mountain View, CA. Technicon, Inc. then propagated it to more than 200 hospitals (see also Chap. 14) (Coffey 1979).

Hospital-based systems provided feedback (decision support) to physicians, which affected clinical decisions and ultimately patient outcomes. The HELP system (Pryor 1988) at LDS Hospital, the Columbia University system (Johnson et al. 1991), the CCC system at Beth Israel Deaconess Medical Center (Slack and Bleich 1999), the Regenstrief System (Tierney et al. 1993; McDonald et al. 1999) at Wishard Memorial Hospital, and others (Giuse and Mickish 1996; Halamka and Safran 1998; Hripcsak et al. 1999; Teich et al. 1999; Cheung et al. 2001; Duncan et al. 2001; Brown et al. 2003) are long-standing systems that add clinical functionality to support clinical care, and set the stage for future systems.

The ambulatory care medical record systems emerged around the same time as inpatient systems but were slower to attract commercial interest than hospital information systems. COSTAR (Barnett et al. 1978; Barnett 1984), the Regenstrief Medical Record System (RMRS) (McDonald et al. 1975), STOR (Whiting-O'Keefe et al. 1985), and TMR (Stead and Hammond 1988) are among the examples. Costar and RMRS are still in use today. The status of ambulatory care records was reviewed in a 1982 report (Kuhn et al. 1984). There are now hundreds of vendors who offer ambulatory care EHRs, and a number of communities have begun to adopt EHRs on a broad scale for ambulatory care (Goroll et al. 2009; Menachemi et al. 2011). Morris Collen, who also pioneered the multiphasic screening system (1969), wrote a readable 500-page history of medical informatics (1995) that provides rich details about these early medical records systems, as does a three decade summary of computer-based medical record research projects from the U.S. Agency for Health Care Policy and Research (AHCPR, now called the Agency for Health Care Research and Quality (AHRQ)) (Fitzmaurice et al. 2002).

12.3 Functional Components of an Electronic Health Record System

As we explained in Sect. 12.1.2, an EHR is not simply an electronic version of the paper record. A medical record that is part of a comprehensive EHR system has linkages and tools to facilitate communication and decision making. In Sects. 12.3.1, 12.3.2, 12.3.3, 12.3.4, and 12.3.5, we summarize the components of a comprehensive EHR system and illustrate functionality with examples from systems currently in use. The five functional components are:

1. Integrated view of patient data
2. Clinician order entry
3. Clinical decision support
4. Access to knowledge resources
5. Integrated communication and reporting support

12.3.1 Integrated View of Patient Data

Providing an integrated view of all relevant patient data is an overarching goal of an EHR. However, capturing *everything* of interest is not

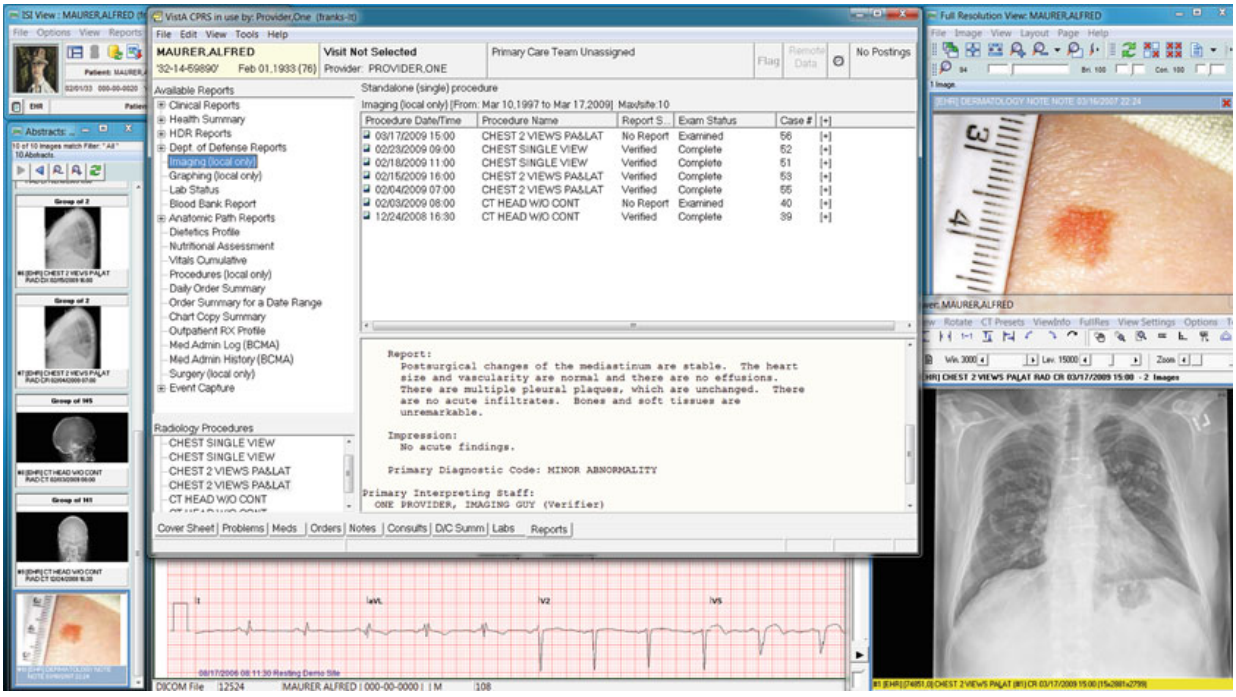

Fig. 12.1 A screenshot of the combined WorldVistA Computer Based Patient Record System (CPRS) and ISI Imaging system. These systems are derived from the Department of Veterans Affairs VistA and VistA Imaging systems (http://www.va.gov/vista_monograph/). The image illustrates the opportunity to present clinical images as well as laboratory test results, medications, notes and other relevant clinical information in a single longitudinal medical record (Source: Courtesy of WorldVistA (worldvista.org) and ISI Group (www.isigp.com), 2012)

yet possible because: (1) Some patient data do not exist in electronic form anywhere, for example, the hand-written data in old charts. (2) Much of the clinical data that do exist in electronic form are sequestered in isolated external computer systems, for example, office practices, free-standing radiology centers, home-health agencies, and nursing homes that do not yet have operational links to a given EHR or each other. (3) Even when electronic and organizational links exist, a fully integrated view of the data may be thwarted by the difference in conceptualization of data among systems from different vendors, and among different installations of one vendor's system in different institutions.

An integrated EHR must accommodate a broad spectrum of data types ranging from text to numbers and from tracings to images and video. More complex data types such as radiology images are usually delivered for human viewing—standards like DICOM[1] exist for displaying most of these complex data types, and JPEG[2] display of images is universally available for any kind of image (see also Chaps. 7 and 9). Figure 12.1 shows the VistA CPRS electronic health record system, which integrates a variety of text data and images into a patient report data screen including: demographics, a detailed list of the patient's procedures, a DICOM chest x-ray image, and JPG photo of a skin lesion. Other tabs in the system provide links to: problems, medications, orders, notes, consults, discharge summary, and labs. An important challenge to the construction of an integrated view is the lack of a national patient identifier in the United States. Because each organization assigns its own medical record number, a receiving organization cannot directly file a patient's data that is only identified by a medical record number from an external care organization. Linking schemes based on name, birth date and other patient characteristics must be implemented and monitored (Zhu et al. 2009).

[1] Digital Imaging and Communications in Medicine, http://dicom.nema.org/ (Accessed 1/2/2013).

[2] JPEG from Wikipedia, the free encyclopedia, http://en.wikipedia.org/wiki/JPEG (Accessed 1/2/2013).

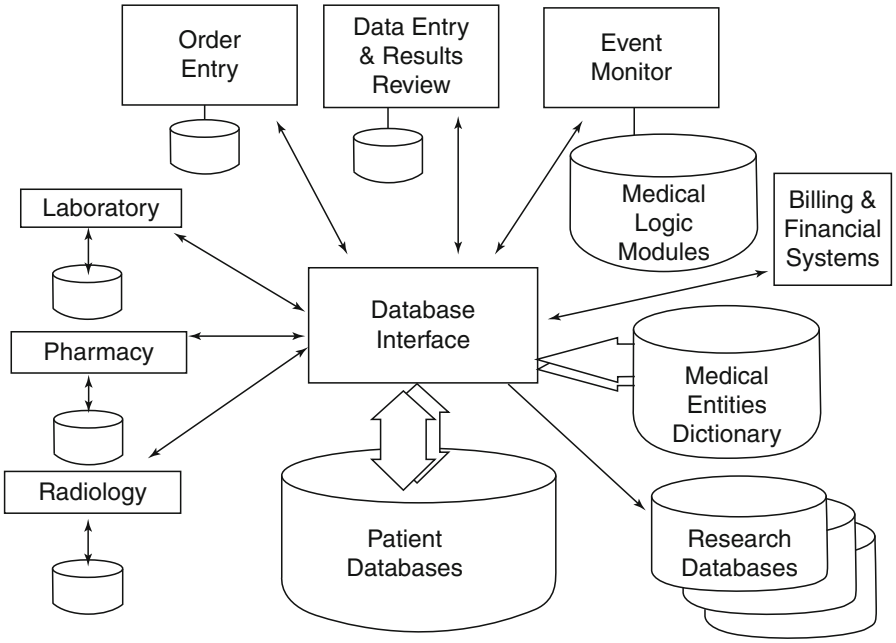

Fig. 12.2 A block diagram of multiple-source-data systems that contribute patient data, which ultimately reside in a computerized patient record (CPR). The database interface, commonly called an interface engine, may perform a number of functions. It may simply be a router of information to the central database. Alternatively, it may provide more intelligent filtering, translating, and alerting functions, as it does at Columbia University Medical Center (Source: Courtesy of Columbia University Medical Center, New York)

The idiosyncratic, local terminologies used to identify clinical variables and their values in many source systems present major barriers to integration of health record data within EHRs. However, those barriers will shrink as institutions adopt code standards (Chap. 7) such as LOINC[3] for observations, questions, variables, and assessments (McDonald et al. 2003; Vreeman et al. 2010); SNOMED CT[4] (Wang et al. 2002) for diagnoses, symptoms, findings, organisms and answers; UCUM[5] for computable units of measure; and RxNorm[6] and RxTerms[7] for clinical drug names, ingredients, and orderable drug names. Federal regulations from CMS and ONC for **Meaningful Use** 2 (MU2) encourage or require the use of LOINC, RxNorm and SNOMED CT for various purposes. (Final Rule: CMS 2012; Final Rule: ONC 2012) (see also Chaps. 7 and 27). Now most laboratory instrument vendors specify what LOINC codes to use for each test result generated by their instruments.

Today, most clinical data sources and EHRs can send and receive clinical content as version 2.× **Health Level 7** (**HL7**)[8] messages. Larger organizations use interface engines to send, receive, and, when necessary, translate the format of, and the codes within, such messages (see Chap. 7); Fig. 12.2 shows an example of architecture to integrate data from multiple source systems. The Columbia University Medical Center computerized patient record (CPR) interface depicted in this diagram not only provides message-handling capability but can also automatically translate codes from the external source to the preferred codes of the receiving EHR. And although many vendors now offer single systems that serve "all" needs, they never escape the need

[3] Logical Observation Identifiers Names and Codes (LOINC®). http://loinc.org/ (Accessed 1/2/2013).

[4] SNOMED Clinical Terms® (SNOMED CT®). http://www.ihtsdo.org/snomed-ct/ (Accessed 1/2/2013).

[5] The Unified Code for Units of Measure. http://unitsofmeasure.org/ (Accessed 1/2/2013).

[6] RxNorm Overview. http://www.nlm.nih.gov/research/umls/rxnorm/overview.html (Accessed 1/2/2013).

[7] RxTerms. https://wwwcf.nlm.nih.gov/umlslicense/rxtermApp/rxTerm.cfm (Accessed 1/2/2013).

[8] Health Level Seven International, http://www.hl7.org/ (Accessed 1/2/2013).

for HL7 interfaces to capture data from some systems, e.g., EKG carts, cardiology systems, radiology imaging systems, anesthesia systems, off-site laboratories, community pharmacies and external collaborating health systems. At least one high-capability open-source interface engine, Mirth Connect,[9] is now available. One of us, (CM), used it happily, for example, in a project that links a local hospital's emergency room to Surescripts' medication history database.[10]

12.3.2 Clinician Order Entry

One of the most important components of an EHR is order entry, the point at which clinicians make decisions and take actions, and the computer can provide assistance. Electronic order entry can improve health care at several levels. An electronic order entry system can potentially reduce errors and costs compared to a paper system, in which orders are transcribed manually from one paper form (e.g., the paper chart) to another (e.g., the nurse's work list or a laboratory request form). Orders collected directly from the decision maker can be passed in a legible form to the intended recipient without the risk of transcription errors or the need for additional personnel. Order entry systems also provide opportunities to deliver decision support at the point where clinical decisions are being made. Most order entry systems pop up alerts about any interactions or allergies associated with a new drug order. But implementers should be selective about which alerts they present and which ones are interruptive, to avoid wasting provider time on trivial or low-likelihood outcomes (Phansalkar et al. 2012a, b). This capability is discussed in greater detail in the next section. Order entry systems can facilitate the entry of simple orders like "vital signs three times a day," or very complicated orders such as total parenteral nutrition (TPN) which requires specification of many additives, and many calculations and checks to avoid physically impossible or dangerous mixtures and to assure that the prescribed goals for the number of calories and the amount of each additive are met. Figure 12.3 shows an example of a TPN order entry screen from Vanderbilt (Miller 2005b). Once a clinician order-entry system is adopted by the practice, simply changing the default drug or dosing based on the latest scientific evidence can shift the physician's ordering behavior toward the optimum standard of care, with benefits to quality and costs. Because of the many potential advantages for care quality and efficiency, care organizations are adopting computerized physician order entry (CPOE) (Khajouei and Jaspers 2010).

12.3.3 Clinical Decision Support

Clinical trials have shown that reminders from decision support improve the care process (Haynes 2011; Damiani et al. 2010; Schedlbauer et al. 2009). The EHR can deliver decision support in batch mode at intervals across a whole practice population in order to identify patients who are not reaching treatment targets, are past due for immunizations or cancer screening, or have missed their recent appointments, to cite a few examples. In this mode, the practice uses the batch list of patients generated by decision support to contact the patient and encourage him or her to reach a goal or to schedule an appointment for the delivery of suggested care. This is the only mode that can reach patients who repeatedly miss appointments.

Decision support—especially related to prevention—is most efficiently delivered when the patient comes to the care site for other reasons (e.g., a regularly scheduled visit). In addition, many kinds of computer suggestions are best delivered during the physician order entry process. For example, order entry is the only point in the workflow at which to discourage or countermand an order that might be dangerous or wasteful. It is also a convenient point to offer reminders about needed tests or treatments, because they will usually require an order for their initiation.

[9] Mirth Corporation Community Overview. http://www.mirthcorp.com/community/overview. (Accessed 1/2/2013).

[10] Surescripts: The Nation's e-Prescription Network http://www.surescripts.com/ (Accessed 1/2/2013).

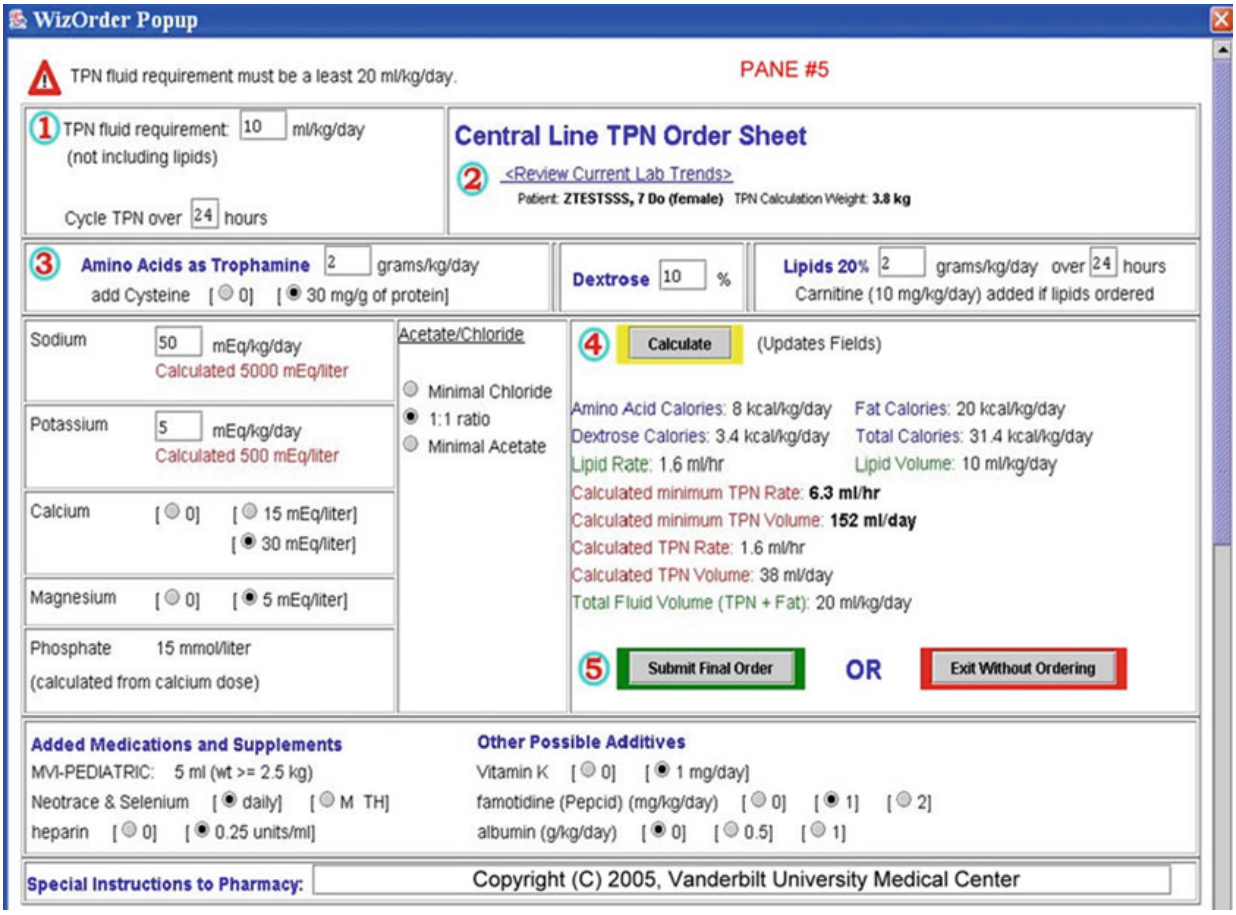

Fig. 12.3 Neonatal Intensive Care Unit (NICU) Total Parenteral Nutrition (TPN) Advisor provides complex interactive advice and performs various calculations in response to the provider's prescribed goal for amount of fluid, calories, nutrition, and special additives (Source: Miller et al. (2005b). Elsevier Reprint License No. 2800411402464)

The best way for the computer to suggest actions that require an order is to present a preconstructed order to the provider who can confirm or reject it with a single key stroke or mouse click. It is best to annotate such suggestions with their rationale, e.g., "the patient is due for his pneumonia vaccine because he has emphysema and is over 65," so the provider understands the suggestion.

Figure 12.4a, b show the suggestions of a sophisticated inpatient decision support system from Intermountain Health Care that uses a wide range of clinical information to recommend antibiotic choice, dose, and duration of treatment. Decision support from the system improved clinical outcomes and reduced costs of infections among patients managed with the assistance of this system (Evans et al. 1998; Pestotnik 2005). Vanderbilt's inpatient "WizOrder" order entry (CPOE) system also addresses antibiotic orders, as shown in Fig. 12.5; it suggests the use of Cefepine rather than ceftazidine, and provides choices of dosing by indication.

Clinical alerts attached to a laboratory test result can include suggestions for appropriate follow up or treatments for some abnormalities (Ozdas et al. 2008; Rosenbloom et al. 2005). Physician order-entry systems can warn the physician about allergies (Fig. 12.6a) and drug interactions (Fig. 12.6b) before they complete a medication order, as exemplified by screenshots from Partner's outpatient medical record orders.

Reminders and alerts are employed widely in outpatient care. Indeed, the outpatient setting is where the first clinical reminder study was performed (McDonald 1976) and is still the setting for the majority of such studies (Garg et al. 2005). Reminders to physicians in outpatient settings quadrupled the use of certain vaccines in eligible patients compared with those who did not receive

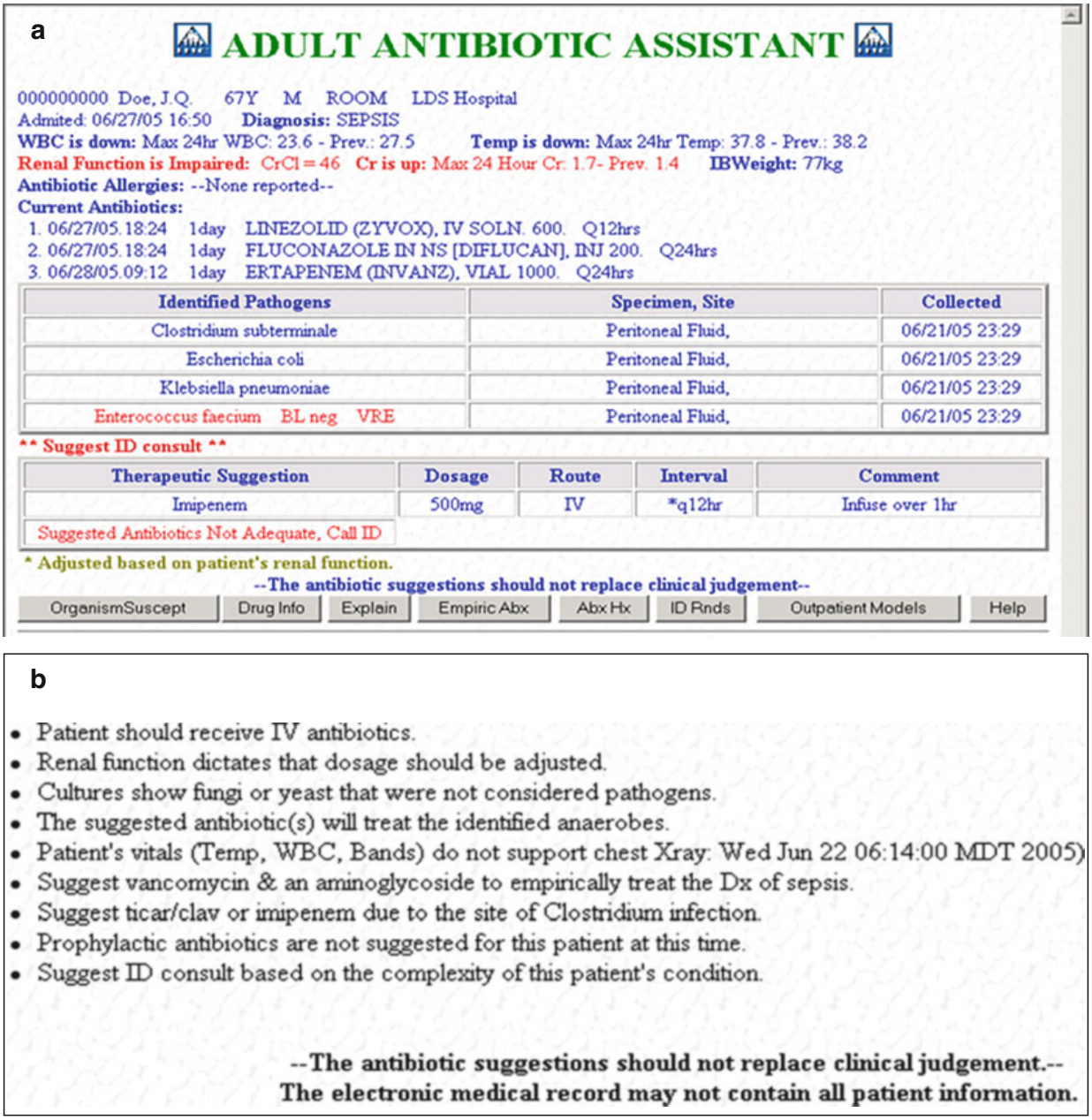

Fig. 12.4 Example of the main screen (**a**) from the Intermountain Health Care Antibiotic Assistant program. The program displays evidence of an infection-relevant patient data (e.g., kidney function, temperature), recommendations for antibiotics based on the culture results, and (**b**) disclaimers (Source: Courtesy of R. Scott Evans, Robert A. Larsen, Stanley L. Pestotnik, David C. Classen, Reed M. Gardner, and John P. Burke, LDS Hospital, Salt Lake City, UT (Larsen et al. 1989))

reminders (McDonald et al. 1984b; McPhee et al. 1991; Hunt et al. 1998; Teich et al. 2000). Reminder systems can also suggest needed tests and treatments for eligible patients. Figure 12.7 shows an Epic system screen with reminders to consider ordering a cardiac echocardiogram and starting an ACE inhibitor—in an outpatient patient with a diagnosis of heart failure but no record of a cardiac echocardiogram or treatment with one of the most beneficial drugs for heart failure.

Though the outpatient setting is the primary setting for preventive care reminders, preventive reminders also can be influential in the hospital (Dexter et al. 2001). And reminders directed to inpatient nurses can improve preventive care as much or more than reminders directed to physicians (Dexter et al. 2004).

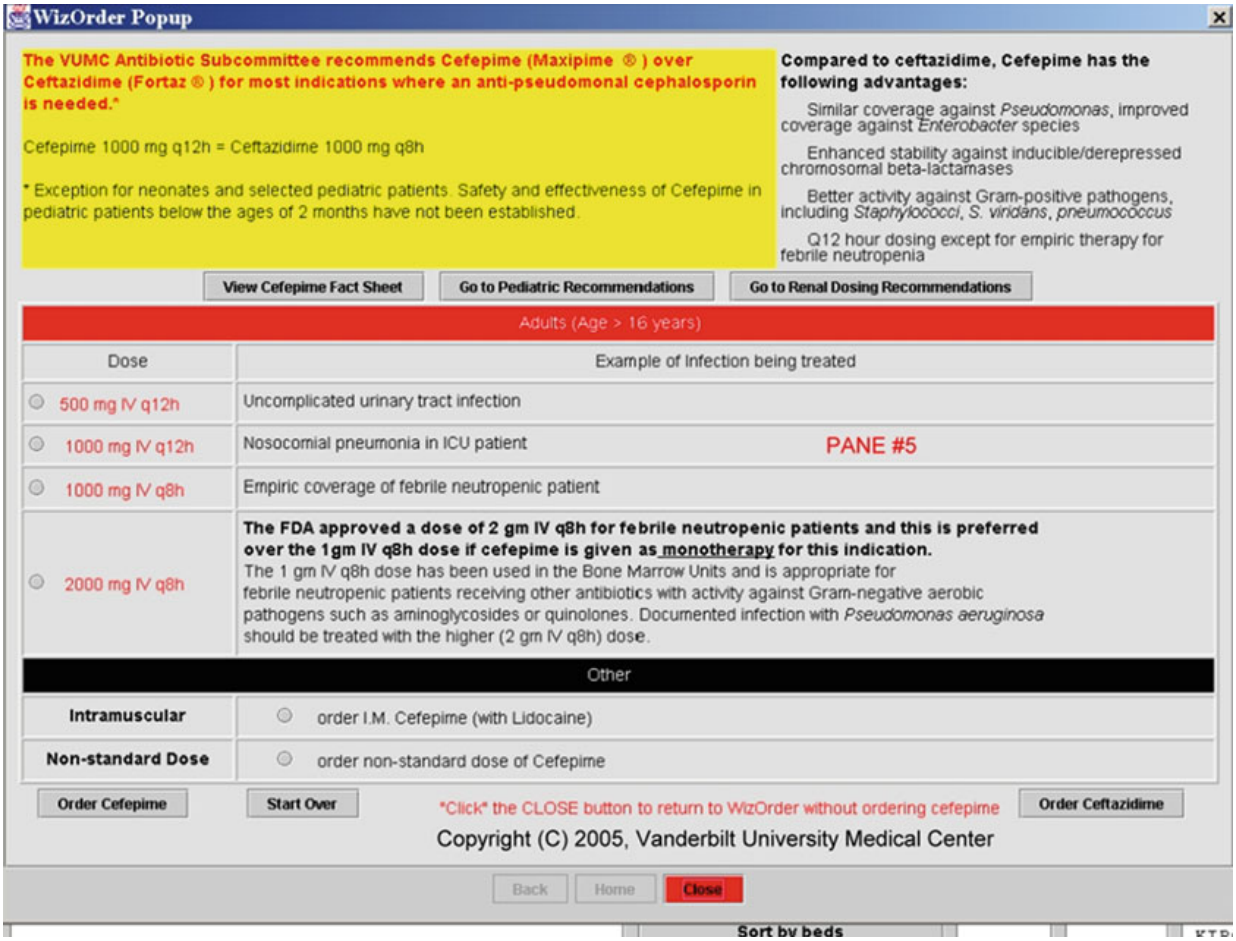

Fig. 12.5 User ordered an antibiotic for which the Vanderbilt's inpatient "WizOrder" order entry (CPOE) system, based on their Pharmaceuticals and Therapeutics (PandT) Committee input, recommended a substitution. This educational advisor guides clinician through ordering an alternative antibiotic. Links to "package inserts" (via buttons) detail how to prescribe recommended drug under various circumstances (Source: Miller, et al. (2005b). Elsevier Reprint License No. 2800411402464)

12.3.4 Access to Knowledge Resources

Most clinical questions, whether addressed to a colleague or answered by searching through text books and published papers, are asked in the context of a specific patient (Covell et al. 1985). Thus, an appropriate time to offer knowledge resources to clinicians is while they are writing notes or orders for a specific patient. Clinicians have access to a rich selection of knowledge sources today, including those that are publically available, e.g. the National Library of Medicine's (NLM) PubMed and MedlinePlus, the Centers for Disease Control and Prevention's (CDC) vaccines and international travel information, the Agency for Healthcare Research and Quality's (AHRQ) National Guideline Clearinghouse, and those produced by commercial vendors such as UpToDate, Micromedex, and electronic textbooks, all of which can be accessed from any web browser at any point in time. Some EHR systems are proactive and present short informational nuggets as a paragraph adjacent to the order item that the clinician has chosen. EHRs can also pull literature, textbook or other sources of information relevant to a particular clinical situation through an **Infobutton** and present that information to the clinician on the fly (Del Fiol et al. 2012), an approach being encouraged by the CMS MU2 regulations (see Fig. 12.8) (Final Rule: CMS 2012).

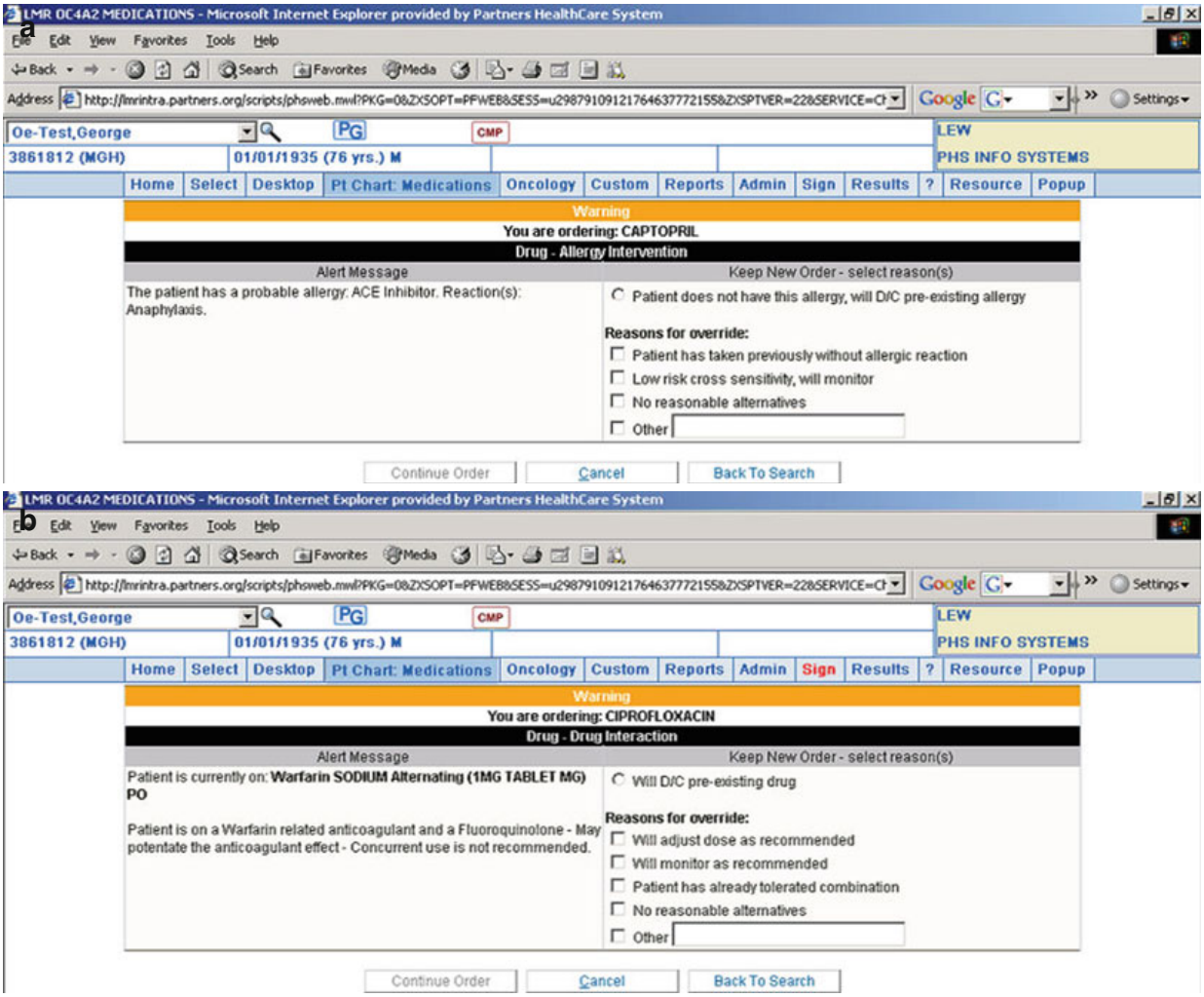

Fig. 12.6 Drug-alert display screens from Partners outpatient medical record application (Longitudinal Medical Record, LMR). The screens show (**a**) a drug-allergy alert for captopril, and (**b**) a drug-drug interaction between ciprofloxacin and warfarin (Source: Courtesy of Partners Health Care System, Chestnut Hill, MA)

12.3.5 Integrated Communication and Reporting Support

Increasingly, the delivery of patient care requires multiple health care professionals and may cross many organizations; thus, the effectiveness, efficiency, and timeliness of communication among such team members and organizations are increasingly important. Such communications usually focus on a single patient and may require a care provider to read content from his or her local EHR or from an external clinical system or to send information from his system to an external system. Therefore, communication tools should be an integrated part of the EHR system.

Ideally providers' offices, the hospital, and the emergency room should all be linked together—not a technical challenge with today's Internet, but still an administrative challenge due to organizational barriers. Connectivity to the patient's home will be increasingly important to patient-provider communication: for delivery of reminders directly to patients (Sherifali et al. 2011), and for home health monitoring, such as home blood pressure (Earle 2011; Green et al. 2008), and glucose monitoring. The patient's personal health record (PHR) will also become an important destination for clinical messages and test results (see Chap. 17). Relevant information can be "pushed" to the user via e-mail or pager services (Major et al. 2002; Poon et al. 2002) or "pulled" by users on demand during their routine interactions with the computer.

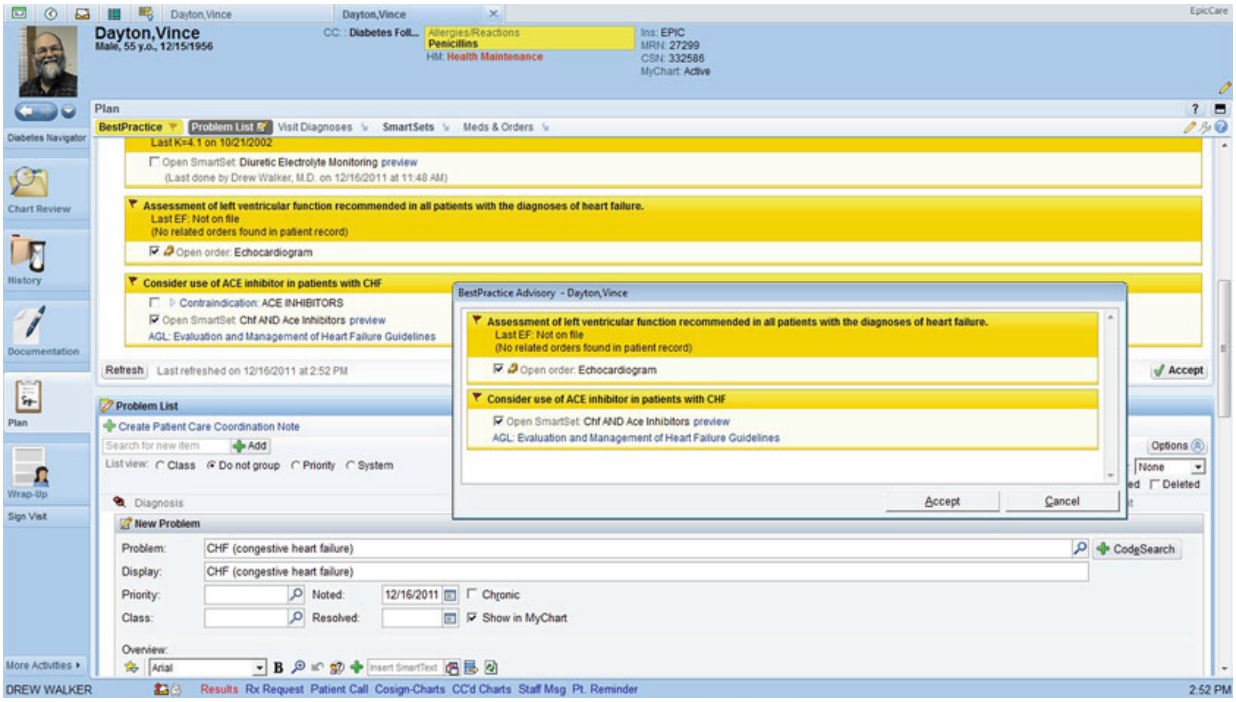

Fig. 12.7 Example of clinical decision support alerts to order an echocardiogram and to start an ACE inhibitor in a patient with diagnosed congestive heart failure (Source: Courtesy of Epic Systems, Madison, WI)

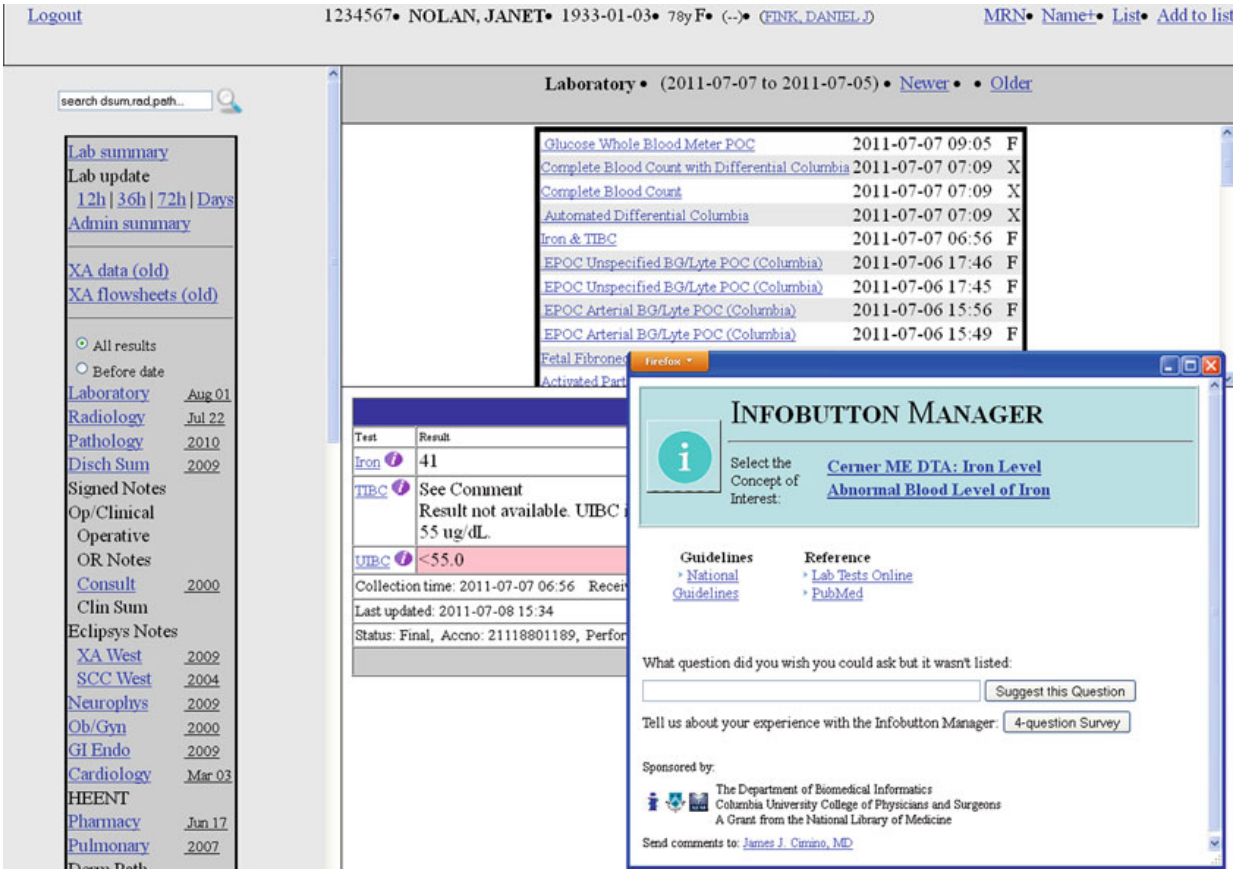

Fig. 12.8 This figure shows the use of Columbia University Medical Center's info-buttons during results review. Clicking on the info-button adjacent to the Iron result generates a window (image) with a menu of questions. When the user clicks on one of the questions, the info button delivers the answers (Source: Courtesy of Columbia University Medical Center, New York)

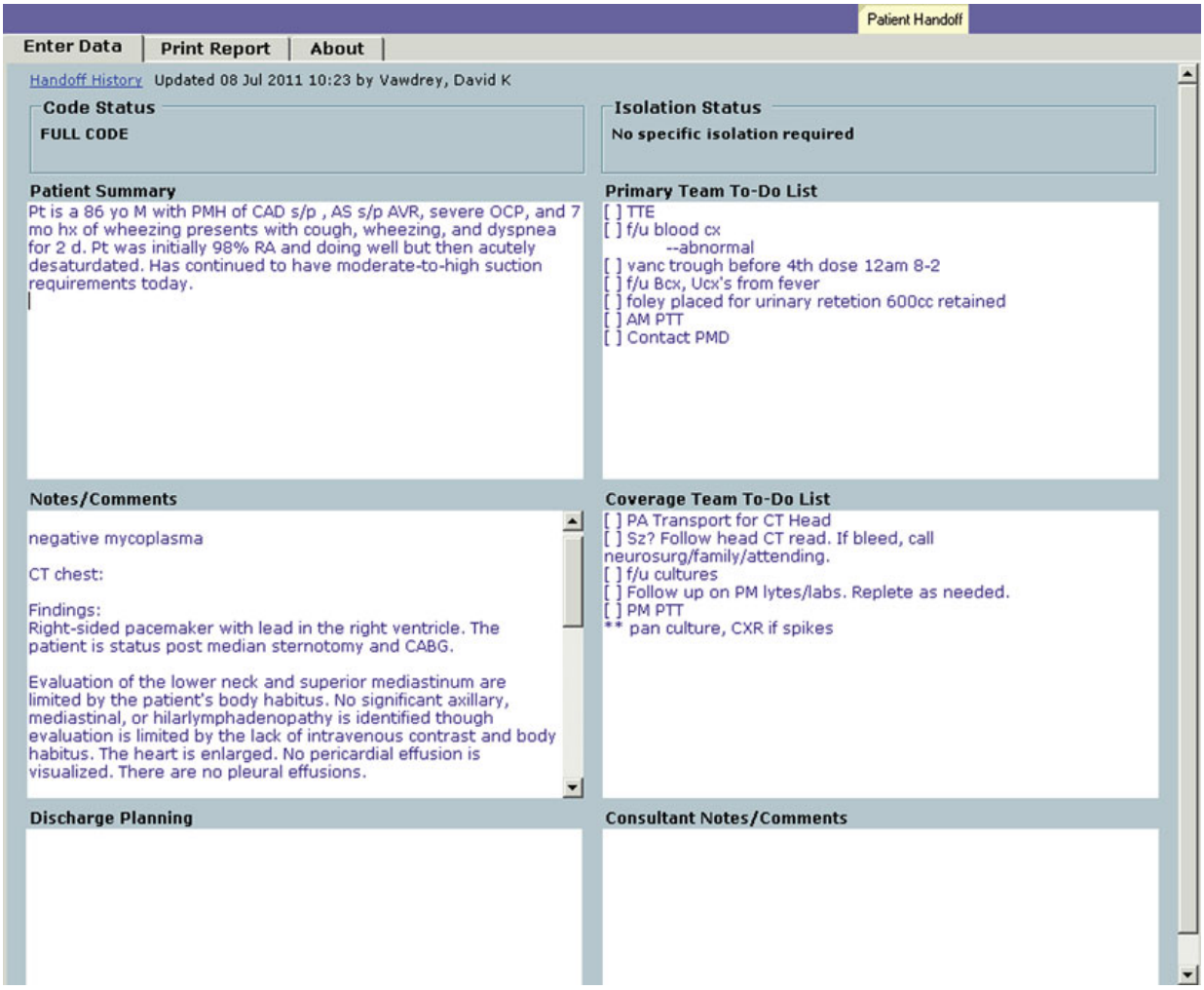

Fig. 12.9 Patient handoff report—a user-customizable hard copy report with automatic inclusion of patient allergies, active medications, 24-h vital signs, recent common laboratory test results, isolation requirements, code status, and other EHR data. This system was developed by a customer within a vendor EHR product (Sunrise Clinical Manager, Allscripts, Chicago, IL) and was disseminated among other customers around the nation (Source: Courtesy of Columbia University Medical Center, New York)

EHR systems can also help with patient handoffs, during which the responsibility for care is transferred from one clinician to another. Typically the transferring clinician delivers a brief verbal or written turn-over note to help the receiving clinician understand the patient's problems and treatments. Figure 12.9 shows an example of a screen that presents a "turn-over report" with instructions from the primary physician, as well as relevant system-provided information (e.g., recent laboratory test results) and a "to-do" list, that ensures that critical tasks are not dropped (Stein et al. 2010). Such applications support communication among team members and improve coordination.

Although a patient encounter is usually defined by a face-to-face visit (e.g., outpatient visit, inpatient bedside visit, home health visit), provider decision making also occurs during patient telephone calls, prescription renewal requests, and the arrival of new test results; so the clinician and key office personnel should be able to respond to these events with electronic renewal authorizations, patients' reports about normal test results, and back-to-work forms as appropriate. In addition, when the provider schedules a diagnostic test such as a mammogram, an EHR system can keep track of the time since the order was written and can notify the physician that a test result has not appeared in a specified time so

that the provider can investigate and correct the obstacle to fulfillment.

EHRs are usually bounded by the institution in which they reside. The National Health Information Infrastructure (NHII) (NCVHS, 2001) proposed a future in which a provider caring for a patient could reach beyond his or her local institution to automatically obtain patient information from any place that carried data about the patient (see Chap. 13). Today, examples of such community-based "EHRs," often referred to as **Health Information Exchanges** (**HIE**), serve routine and emergency care, public health and/or other functions. A few examples of long-existing HIEs are those in: Indiana (McDonald et al. 2005), Ontario, Canada (electronic Child Health Network),[11] Kentucky (Kentucky Health Information Exchange),[12] and Memphis (Frisse et al. 2008).[13] A study from this last system showed that the extra patient information provided by this HIE reduced resource use and costs (Frisse et al. 2011). The New England Health care Exchange Network (NEHEN)[14] has created a community-wide collaborative system for managing eligibility, preauthorization, and claim status information (Fleurant et al. 2011).

The **Office of the National Coordinator** (**ONC**) has developed two communication tools to support the **Nationwide Health Information Network** (**NwHIN**)[15] and health data exchange (see Chaps. 13 and 27). NwHIN Connect[16] is an HHS project designed for pulling information from any site within a national network of health care systems. It offers a sophisticated consenting system by which patients can control who can use and see their information, but has only been used in a few pairs of communicating institutions. **NwHIN Direct**[17] is a much simpler approach that uses standard Web Email, **domain name system** (**DNS**) and **public-private keys** to push patient reports as encrypted email messages from their source (e.g. laboratory system) to clinicians and hospitals. It could also be used to link individual care organizations to an HIE. Microsoft, among others, has implemented NwHIN Direct.

Communication tools that support timely and efficient communication between patients and the health care team can enhance coordination of care and disease management, and eHealth applications can provide patients with secure online access to their EHR and integrated communication tools to ask medical questions or conveniently perform other clinical (e.g., renew a prescription) or administrative tasks (e.g., schedule an appointment) (Tang 2003).

12.4 Fundamental Issues for Electronic Health Record Systems

All health record systems must serve the same functions, whether they are automated or manual. From a user's perspective, the major difference is the way data are entered into, and delivered from, the record system. In this section, we explore the issues and alternatives related to data entry and then describe the options for displaying and retrieving information from an EHR.

12.4.1 Data Capture

EHRs use two general methods for **data capture**: (1) electronic interfaces from systems, such as laboratory systems that are already fully automated, and (2) direct manual data entry, when no such electronic source exists or it cannot be accessed.

[11] eCHN electronic Child Health Network. http://www.echn.ca/ (Accessed 1/2/2013).

[12] Kentucky Health Information Exchange Frequently Asked Questions. http://khie.ky.gov/Pages/faq.aspx?fc=010 (Accessed 1/2/2013).

[13] MidSoutheHealth Alliance. http://www.midsoutheha.org (Accessed 1/2/2013).

[14] New England Health care Exchange Network (NEHEN). www.nehen.net (Accessed 1/2/2013).

[15] http://www.healthit.gov/policy-researchers-implementers/nationwide-health-information-network-nwhin (Accessed 1/3/2013).

[16] http://www.healthit.gov/policy-researchers-implementers/connect-gateway-nationwide-health-information-network (Accessed 1/3/2013).

[17] Office of the National Coordinator for Health Information Technology. Direct Project http://directproject.org/ (Accessed 1/2/2013).

12.4.1.1 Electronic Interfaces

The preferred method of capturing EHR data is to implement an electronic interface between the EHR and the existing electronic data sources such as laboratory systems, pharmacy systems, electronic instruments, home monitoring devices, registration systems, scheduling systems, etc.

The creation of interfaces requires effort to implement as described under Sect. 12.3.1, but, once implemented they provide near-instant availability of the clinical data without the labor costs and error potential of manual transcription. Interfacing is usually easier when the organization that owns the EHR system also owns, or is tightly affiliated with, the source system. Efforts to interface with systems outside the organizational boundary can be more difficult. However, interfaces between office practice systems and major referral laboratories for exchanging laboratory test orders and results, and between hospitals and office practices to pharmacies for e-prescribing, are now relatively easy and quite common.

The above discussion about interfacing concerns data produced, or ordered, by a home organization. However, much of the information about a patient will be produced or ordered by an outside organization and will not be available to a given organization via any of the conventional interfaces described above. For example, a hospital-based health care system will not automatically learn about pediatric immunizations done in private pediatric offices, or public health clinics, around town. So, special procedures and extra work are required to collect all relevant patient data. The promotion of health information exchange stimulated by passage of the Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009 (see Chap. 27) and other information exchange mechanisms (e.g. NwHIN Direct) described in Sect. 12.3.5 will facilitate the capture of such information from any source (see Chaps. 7 and 13).

12.4.1.2 Manual Data Entry

Data may be entered as narrative free-text, as codes, or as a combination of codes and free text annotation. Trade-offs exist between the use of codes and narrative text. The major advantage of coding is that it makes the data "understandable" to the computer and thus enables selective retrieval, clinical research, quality improvement, and clinical operations management. The coding of diagnoses, allergies, problems, orders, and medications is of special importance to these purposes; using a process called auto complete, clinicians can code such items by typing in a few letters of an item name, then choosing the item they need from the modest list of items that match the string they have entered. This process can be fast and efficient when the computer includes a full range of synonyms for the items of interest, and has frequency statistics for each item, so that it can present a short list of the most frequently occurring items that match the letters the user has typed so far.

Natural-language processing (NLP) (see Chap. 8) offers hope for automatic encoding of narrative text (Nadkarni et al. 2011). There are many types of NLP systems, but in general, such systems first regularize the input to recognize sections, sentences, and tokens like words or numbers. Through a formal grammar or a statistical technique, the tokens are then mapped to an internal representation of concepts (e.g., specific findings), their modifiers (e.g., whether a finding was asserted as being present or denied, and the timing of the finding), and their relations to other concepts. The internal representation is then mapped to a standard terminology and data model for use in a data warehouse or for automated decision support.

12.4.1.3 Physician-Entered Data

Physician-gathered patient information requires special comment because it presents the most difficult challenge to EHR system developers and operators. Physicians spend about 20 % of their time documenting the clinical encounter (Gottschalk and Flocke 2005; Hollingsworth et al. 1998). And the documentation burden has risen over time, because patient's problems are more acute, care teams are larger, physicians order more tests and treatments, and billing regulatory bodies demand more documentation.

Many believe that clinicians themselves should enter all of this data directly into the EMR under the assumption that the person who collects the data should enter it. This tactic makes the most sense for prescriptions, orders, and perhaps diagnoses and procedure codes, whose immediate entry during the course of care will speed service to the patient and provide crucial grist for decision support. Direct entry by clinicians may not be as important for visit notes because the time cost of physician input is high and the information is not a pre-requisite to the check-out process.

Physicians' notes can be entered into the EHR via one of three general mechanisms: (1) transcription of dictated or written notes, (2) clinic staff transfer or coding of some or all of the data by clinicians on a paper encounter form, and (3) direct data entry by physicians into the EHR (which may be facilitated by electronic templates or macros). Dictation with **transcription** is a common approach for entering narrative information into EHRs. If physicians dictate their reports using standard formats (e.g., present illness, past history, physical examinations, and treatment plan), the transcriptionist can maintain a degree of structure in the transcribed document via section headers, and the structure can also be delivered as an HL7 CDA document (Ferranti et al. 2006).

Some practices have employed scribes (a variant on the stenographers of old) to some of the physicians' data entry work (Koshy et al. 2010), and CMS's MU2 regulation (Final Rule: CMS 2012) allows credentialed medical assistants to take on this same work. **Speech recognition** software offers an approach to "dictating" without the cost or delay of transcription. The computer translates the clinician's speech to text automatically. However, even with accuracy rates of 98 %, users may have to invest important amounts time to find and correct these errors.

Some dictation services use speech recognition to generate a draft transcription, which the transcriptionist corrects while listening to the audio dictation, thus saving transcriptionist time; others are exploring the use of natural language processing (NLP) to auto-encode transcribed text, and employ the transcriptionist to correct any NLP coding errors (see Chap. 8).

The second data-entry method is to have physicians record information on a **structured encounter form**, from which their notes are transcribed or possibly scanned (Downs et al. 2006; Hagen et al. 1998). One system (Carroll et al. 2011) uses paper turn-around documents to capture visit note data in one or more steps. First, the computer generates a child-specific data-capture form completed by the mother and the nursing staff. The computer scans the completed form (Fig. 12.10a), reads the hand-entered numeric data (top of form), check boxes (middle of form) and the bar codes (bottom of form), and stores them in the EHR. Next, the computer generates a physician encounter form that is also child-specific. The physician completes this form (Fig. 12.10b) and the computer processes it the same way it processed the nursing form.

The third alternative is the **direct entry** of data into the computer by care providers. This alternative has the advantage that the computer can immediately check the entry for consistency with previously stored information and can ask for additional detail or dimensions conditional on the information just entered. Some of this data will be entered into fields which require selection from pre-specified menus. For ease of entry, such menus should not be very long, require scrolling, or impose a rigid hierarchy (Kuhn et al. 1984). A major issue associated with direct physician entry is the physician time cost. Studies document that structured data entry consumes more clinician time than the traditional record keeping (Chaudhry et al. 2006), as much as 20s per SNOMED CT coded diagnoses (Fung et al. 2011)—which may be a function of the interface terminology used (or not used), and a small study suggests that the EHR functions taken together may consume up to 60 min of the physician's free time per clinic day (McDonald and McDonald 2012). So, planners must be sensitive to these time costs. In one study, the computer system was a primary cause of clinician dissatisfaction (Edgar 2009) and their reason for leaving military medicine.

The use of templates and menus can speed note entry, but they can also generate excessive boilerplate and discourage specificity, i.e., it is easier to pick an available menu option than to

a 1618149875

CHICA Pre-Screening

MRN: #9999999-7
Name: Patient, Jenny D
Age: 2 yo DOB: Nov 18 2009
Date: Nov 29 2011

Height: 84.5 cm.
Weight: 14.2 kg.
HC: . cm.
BP: /
Temp: . deg. F
Pulse: /min RR:

Uncooperative / Unable to Screen: ☐ Vision ☐ Hearing ☐ BP

Vision Left: 20/
Vision Right: 20/

Left Ear @ 25db: P F
Right Ear @ 25db: P F

Pulse Ox: %

☐ Sick Visit
☐ Two IDs checked
☐ Patient refused to complete form
☐ Patient left without treatment

Box For Nursing Use Only - Box For Nursing Use Only - Box For Nursing Use Only - Box For Nursing Use Only

Parents: Thank you for answering these questions about your child. The answers will help your doctor provide better quality of care. If your child is age 11 or older, he/she should answer the questions privately. Answers are confidential, but if you prefer not to answer that is allowed. You may want to talk about these questions with your doctor.

Please fill in the circles completely with a pencil or pen.

Y	N		Y	N	
○	⊗	Is Jenny having pain today?	⊗	○	Please fill out the attached form about Jenny's development.
○	⊗	Does Jenny take prescription or over-the-counter medicine, herbal medicine or vitamins, or use an inhaler or medicated creams or lotions?	⊗	○	Can Jenny take off any of her clothes, such as pajamas (tops or bottoms) or pants? Do not count diapers, hats, socks, or shoes.
⊗	○	Does Jenny say six or more words other than 'Mama', 'Dada' and names of family members or pets?	⊗	○	Do you feel safe in your home?
⊗	○	Has your partner kicked, hit, or slapped you?	○	⊗	Jenny has sickle cell disease (HbSS). Is she taking antibiotics twice a day, every day?
⊗	○	Does Jenny always wear a helmet when riding her bike or tricycle?	⊗	○	Does Jenny have a TV in her room?
⊗	○	Does Jenny usually watch TV or computer more than 2 hours a day?	⊗	○	Does anyone in Jenny's home smoke?
⊗	○	Do you know what to do if Jenny is choking?	○	⊗	Has Jenny ever been around water when an adult has not been within an arm's length?
○	⊗	Has your partner or another adult threatened or hurt your children?	○	⊗	Does Jenny ever use a bottle?
○	⊗	Has Jenny seen a dentist this year?	⊗	○	Is Jenny on the WIC program?
○	⊗	Are any firearms or guns kept in Jenny's home?	⊗	○	Has Jenny spent more than a week in Asia, Africa, Latin America or Eastern Europe?

Preguntas en español al otro lado.

Fig. 12.10 (**a**) Nurse/mother completes the first form with questions tailored to patient's age. An OCR system reads the hand written numbers at top, the check boxes in center and bar code identifiers at the bottom and passes the content to the EHR. (**b**) The computer generates a physician encounter form based on the contents of the first form and adds reminders. The OCR system interprets the completed form, encodes the answers given in the check boxes, and stores the hand writing as image as part of the visit note (Source: Courtesy of Regenstrief Institute, Indianapolis, IN)

b 9784258913 **CHICA Physician Encounter Form** **#9999999-7**

Patient: Patient, Jenny D (F) **MRN:** #9999999-7
DOB: 11/18/09 **Age:** 2 yo **Date:** Nov 29 2011
Doctor: Stephen Downs **Time:** 4:29PM

Physical Exam: (Nl Abnl)
General: * ☒ ☐
Head: ☒ ☐
Skin: ☒ ☐
Eyes: * ☐ ☒ -Esotropia
Ears: * ☒ ☐ -OM resolved
Nose / Throat: * ☒ ☐
Teeth / Gums: ☒ ☐
Nodes: * ☒ ☐
Chest / Lungs: * ☒ ☐ -Nonwheezing
Heart / Pulses: ☒ ☐
Abdomen: ☒ ☐
Ext. Genitalia: ☒ ☐
Back: ☒ ☐
Neuro: ☒ ☐
Extremities: ☒ ☐
Legend: * = Previously Abnl
o = Needs Examination

History / Exam Comments:
CC :
☐ Additional notes on back...
☐ Two ID's Checked
Informant: _____

2yo w/SCD - not taking prophylaxis. Mom reports violence in home. Referred to Julian Ctr. Jenny's devel is OK, but she is overweight. Dietary counselling given. Recent travel to Mexico

A **Vital Signs:**
Height: 84.5 cm. (35 %)
Weight: ~~14.2~~ kg.(92 %)
* BMI: 19.9 (98 %)
Head Circ: cm.(%)
Temp: F
Pulse:
RR:
BP:
Pulse Ox: %
Hear (L): Hear (R):
Vision (L):
Vision (R):
Weight: 31.31 lb.
* = Abnormal, U = Uncooperative

Allergies: None
medications: NONE
Pain (0-10): 0

INSTRUCTIONS: Check all applicable boxes. COMPLETELY fill space to right of each box to "uncheck" misfilled boxes.

Child has confirmed SCD. If Jenny has sickle cell disease, then proper maintenance includes antibiotic prophylaxis and yearly influenza vaccinations.

☒ Penicillin V 125mg BID ☐ Erythromycin if PCN allergic
☒ Influenza Vaccine given ☐ Refer to Hem/Onc
☐ Patient confirmed SCD ☐ Patient does NOT have SCD

Jenny's parent reported being abused or feeling unsafe on 11/29/11. If you can speak confidentially and confirm risk of domestic violence, assess for child abuse and advise parent:

☒ Dom Viol Network 317-920-9320 ☒ Pack $ & clothes for escape
☐ Offer social services here ☐ Don't suspect Dom viol
☐ Suspect child abuse --> Report ☐ Can't speak confidentially

TV: Jenny has a TV in bedroom, watches >2hrs of TV per day, so the following advice is recommended.

☒ Advise <2hrs TV/computer per ☐
☒ Advise to remove TV from ☐
☐ ☐

DENTAL: Remind family that parent should help Jenny brush teeth twice daily, and that Jenny should see a dentist every year. (See handout)

☒ Rec: parent help brush BID ☐ Rec: not eat/drink at bed
☒ Advise to see dentist ☒ Gave dentist handout
☒ Mouth/teeth healthy on exam ☐ Abnl oral exam (see note)

DENTAL: Children should see a dentist at least annually beginning at age 1 year. Jenny may not have seen a dentist this year. Handout with dentists attached.

☒ Advise to see dentist ☐
☒ Given handout ☐
☐ Has seen dentist this year ☐

High TB Risk Patient: Jenny reportedly has travelled to a TB endemic country. Place PPD 5TU IQ now.

☐ PPD already done -> ☐ Positive
☐ PPD not indicated ☐ Negative
☒ PPD placed ☐ PPD deferred/refused

Assessments and Plan:
☐ The medical student acted as a scribe for this note.

Referred to Julian center
Pen VK prescribed as above

Medication Education Performed and/or Counseled on Vaccines: ☐ Y ☐ N ☐ N/A

Flu shot today
PPD placed.
Ref to dentist. F/u 2wk

Staff: _____
Signature: _____

Fig. 12.10 (continued)

describe a finding or event in detail. Further, with templates, the user may also accept default values too quickly so notes written via templates may not convey as clear a picture of the patient's state as a note that is composed free-form by the physician and may contain inaccurate information.

Free-form narrative entry—by typing, dictation, or speech recognition—allows the clinician to express whatever they deem to be important. When clinicians communicate, they naturally prioritize findings and leave much information implicit. For example, an experienced clinician often leaves out "pertinent negatives" (i.e., findings that the patient does not have but that nevertheless inform the decision making process) knowing that the clinician who reads the record will interpret them properly to be absent. The result is usually a more concise history with a high signal-to-noise ratio that not only shortens the data capture time but also lessens the cognitive burden on the reading clinician. Weir and colleagues present compelling evidence about these advantages, especially when narrative is focused and vivid, and emphasize that too much information interferes with inter-provider communication (Weir et al. 2011).

Most EHRs let physicians cut and paste notes from previous visits and other sources. For example, a physician can cut and paste parts of a visit note into a letter to a referring physician and into an admission note, a most appropriate use of this capability. However, this cutting and pasting capability can be over-used and cause 'note bloat.' In addition, without proper attention to detail, some information may be copied that is no longer pertinent or true. In one study, 58 % of the text in the most recent visit notes duplicated the content of a previous note (Wrenn et al. 2010), although of course some repetition from note to note can be appropriate.

Tablets and smart phones provide new opportunities for data capture by clinical personnel including physicians. The University of Washington (Hartung et al. 2010) has developed a sophisticated suite of open source tools called the Open Data Interface (ODI) that includes form design and deployment to smart phones as well as delivery of captured data to a central resource. Data capture can be fast, and physicians and health care assistants in some third-world countries are using these tools eagerly. Figure 12.11 shows four screen shots from a medical record application of ODI. The first (Fig. 12.11a) is the patient selection screen. After choosing a patient, the user can view a summary of the patient's medical record. Scrolling is usually required to view the whole summary. Figure 12.11b, c show screen shots of two portions of the summary. Users can

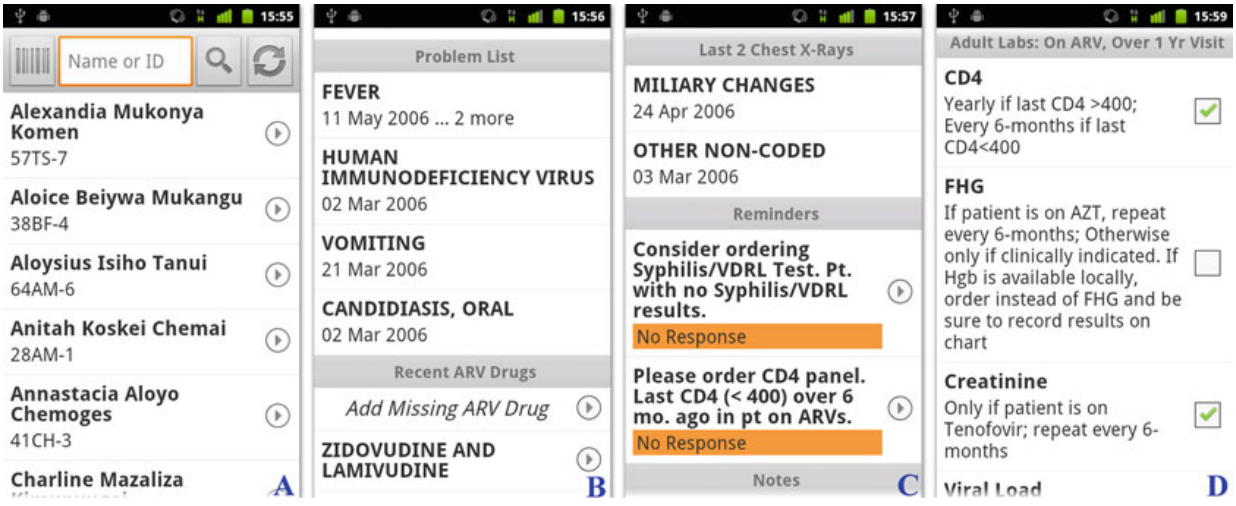

Fig. 12.11 ODK Clinic is a mobile clinical decision support system that helps providers make faster and better decisions about care. Providers equipped with ODK Clinic on a mobile phone or tablet can (**a**) access a list of patients (**b**) and (**c**) download patient summaries that include data from one patient record about diagnoses, diseases, reminders, and (**d**) specific lab data from an OpenMRS electronic medical record system. Summaries can be customized for specific diseases (i.e., for a provider treating a adult HIV patient). Users can also print lab orders on nearby printer and enter clinical data into some applications. The application is the result of a collaboration between USAID-AMPATH, the University of Washington, and the Open Data Kit project (Used with permission of Univ. of Washington. Find out more at: http://opendatakit.org)

choose to see the details of many kinds of information. Figure 12.11d shows the details of a laboratory test result. ODI ties into the OpenMRS project (Were et al. 2011), which has also been adopted widely in developing countries.

The long-term solution to data capture of information generated by clinicians is still evolving. The current ideal is the semi-structured data entry, which combines the use of narrative text fields and formally structured fields that are amenable to natural language processing combined with structured data entry fields where needed. With time and better input devices, direct computer entry will become faster and easier. In addition, direct entry of some data by patients will reduce the clinician's data entry (Janamanchi et al. 2009).

12.4.1.4 What to Do About Data Recorded on Paper Before the Installation of the EHR

Care organizations have used a number of approaches to load new EHR systems with pre-existing patient data. One approach is to interface the EHR to available electronic sources—such as a dictation service, pharmacy systems, and laboratory information systems—and load data from these sources for 6–12 months before going live with the EHR. A second approach is to abstract selected data, e.g., key laboratory results, the problem lists, and active medications from the paper record and hand enter those data into the EHR prior to each patient's visit when the EHR is first installed. The third approach is to scan and store 1–2 years of the old paper records. This approach does solve the availability problems of the paper chart, and can be applied to any kind of document, including handwritten records, produced prior to the EHR installation. Remember that these old records will have to be labeled with the patient ID, date information, and, preferably, the type of content (e.g., laboratory test, radiology report, provider dictation, and discharge summary, or, even better, a precise name, such as chest x-ray or operative note) and this step requires human effort. **Optical Character Recognition** (**OCR**) capability is built into most document scanners today, and converts typed text within scanned documents to computer understandable text with 98–99 % character accuracy.

12.4.1.5 Data Validation

Because of the chance of transcription errors with the hand entry of data, EHR systems must apply **validity checks** scrupulously. A number of different kinds of checks apply to clinical data (Schwartz et al. 1985). **Range checks** can detect or prevent entry of values that are out of range (e.g., a serum potassium level of 50.0 mmol/L—the normal range for healthy individuals is 3.5–5.0 mol/L). The computer can ask the users to verify results beyond the absolute range. **Pattern checks** can verify that the entered data have a required pattern (e.g., the three digits, hyphen, and four digits of a local telephone number). **Computed checks** can verify that values have the correct mathematical relationship (e.g., white blood cell differential counts, reported as percentages, must sum to 100). **Consistency checks** can detect errors by comparing entered data (e.g., the recording of cancer of the prostate as the diagnosis for a female patient). **Delta checks** warn of large and unlikely differences between the values of a new result and of the previous observations (e.g., a recorded weight that changes by 100 lb in 2 weeks). **Spelling checks** verify the spelling of individual words.

12.4.2 Data Display

Once stored in the computer, data can be presented in numerous formats for different purposes without further entry work. In addition, computer-stored records can be produced in novel formats that are unavailable in manual systems.

Increasingly, EHRs are implemented on web browser technology because of the ease of deployment to any PC or smart device (including smart phone and tablets; see Chap. 14) so health care workers (e.g., physicians on call) can view patient data off-site. Advanced web security features such as **Transport Layer Security** (**TLS**) (NIST 2005)—a revised designation for **Secure**

Sockets Layer (**SSL**)—can ensure the confidentiality of any such data transmitted over the Internet.

Here, we discuss a few helpful formats. Clinicians need more than just integrated access to patient data; they also need various views of these data: in chronologic order as flowsheets or graphs to highlight changes over time, and as snapshots that show a computer view of the patients' current status and their most important observations.

12.4.2.1 Timeline Graphs

A graphical presentation can help the physician to assimilate the information quickly and draw conclusions (Fafchamps et al. 1991; Tang and Patel 1994; Starren and Johnson 2000). An anesthesia system vendor provides an especially good example of the use of numbers and graphics in a timeline to convey the patient's state in form that can be digested at a glance (Vigoda and Lubarsky 2006). Sparklines—"small, high resolution graphics embedded in a context of words, numbers, images" (Tufte 2006), which today's browsers and spreadsheets can easily generate—provide a way to embed graphic timelines into any report. One study found that with sparklines, "physicians were able to assess laboratory data faster … enable more information to be presented in a single view (and more compactly) and thus reduce the need to scroll or flip between screens" (Bauer et al. 2010). The second column of the flowsheet in Fig. 12.12a displays sparklines that include all of the data points for a given variable. The yellow band associated with those sparklines highlights the reference range. Clicking on one or more sparklines produces a pop-up that displays a standard graph for all of the selected variables. The user can expand the timeline of this graph to spread out points that are packed too closely together as shown in Fig. 12.12b.

12.4.2.2 Timeline Flowsheets

Figure 12.13a shows an integrated view of a flowsheet of the radiology impressions with the rows representing different kinds of radiology examinations and the columns representing study dates. Clicking on the radiology image icon brings up the radiology images, e.g., the quarter resolution chest X-ray views in Fig. 12.13b. An analogous process applies to electrocardiogram (ECG) measurements where clicking on the ECG icon for a particular result brings up the full ECG tracing in Portable Document Format (PDF) form. Figure 12.14 shows the popular pocket rounds report that provides laboratory and nursing measurements as a very compact flowsheet that fits in a white coat pocket (Simonaitis et al. 2006).

Flowsheets can be specialized to carry information required to manage a particular problem. A flowsheet used to monitor patients who have hypertension (high blood pressure) for example might contain values for weight, blood pressure, heart rate, and doses of medications that control hypertension as well as results of laboratory tests that monitor complications of hypertension, or the medications used to treat it. Systems often permit users to adjust the time granularity of flowsheets on the fly. An ICU user might view results at minute-by-minute intervals, and an out-patient physician might view them with a month-by-month granularity.

12.4.2.3 Summaries and Snapshots

EHRs can highlight important components (e.g., active allergies, active problems, active treatments, and recent observations) in clinical summaries or snapshots (Tang et al. 1999b). Figure 12.15 from Epic's product shows an example that presents the active patient problems, active medications, medication allergies, health maintenance reminders, and other relevant summary information. These views are updated automatically with any new data entry so they are always current. In the future, we can expect more sophisticated summarizing strategies, such as automated detection of adverse events (Bates et al. 2003b) or automated time-series events (e.g., cancer chemotherapy cycles). We may also see reports that distinguish abnormal changes that have been explained or treated from those that have not, and displays that dynamically organize the supporting evidence for existing problems (Tang and Patel 1994; Tang et al. 1994a).

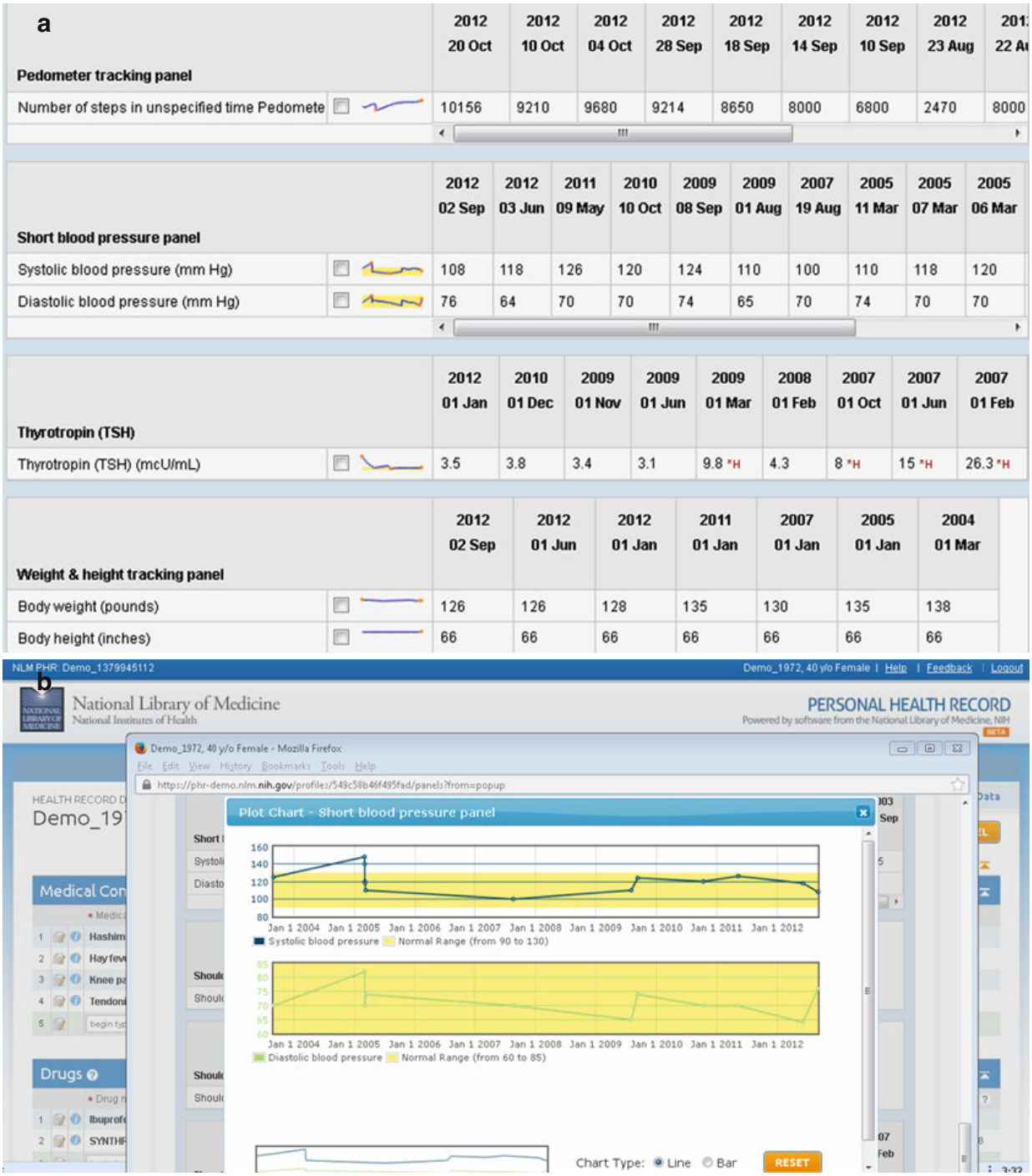

Fig. 12.12 The National Library of Medicine Personal Health Record (PHR) flow sheet (**a**) allows the consumer to track test, treatments and symptoms over time. Clicking on a sparklines graph in the flow sheet table opens a larger plot chart view (**b**) consumers can click on multiple sparklines to obtain full-sized graphs of the selected variables on one page. They can also mouse over a specific data point on the chart to expand the timeline, as shown shaded in *pink* (Source: Courtesy of Clement J. McDonald, Lister Hill National Center for Biomedical Communications, National Library of Medicine, Bethesda, MD)

Ultimately, computers should be able to produce concise and flowing summary reports that are like an experienced physician's hospital discharge summary.

12.4.2.4 Dynamic Search

Anyone who has reviewed a patient's chart knows how hard it can be to find a particular piece of information. From 10 % (Fries 1974) to

81 % (Tang et al. 1994b) of the time, physicians do not find patient information that has been previously recorded in a paper medical record. Furthermore, the questions clinicians routinely ask are often the ones that are difficult to answer from perusal of a paper-based record. Common questions include whether a specific test has ever been performed, what kinds of medications have been tried, and how the patient has responded to particular treatments (e.g., a class of medications) in the past. Physicians constantly ask these questions as they flip back and forth in the chart searching for the facts to support or refute one in a series of evolving hypotheses. Search tools (see Sect. 12.4.3) help the physician to locate relevant data. The EHR can then display these data as specialized presentation formats (e.g., flowsheets or graphics) to make it easier for them to draw conclusions from the data. A graphical presentation can help the physician to assimilate the information quickly and to draw conclusions (Fafchamps et al. 1991; Tang et al. 1994a; Starren and Johnson 2000).

12.4.3 Query and Surveillance Systems

The **query** and **surveillance** capabilities of computer-stored records have no counterpart in manual systems. Medical personnel, quality

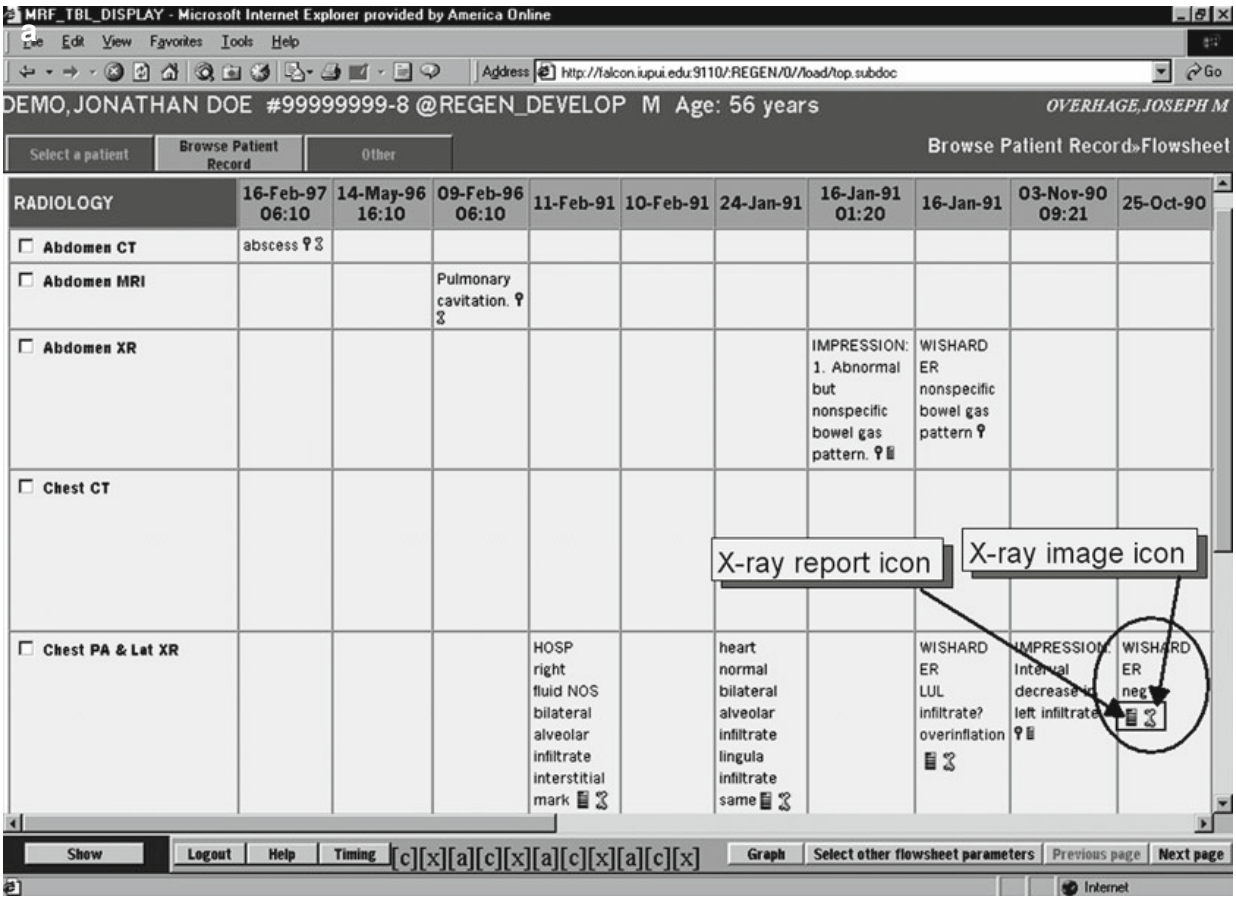

Fig. 12.13 Web resources. (**a**) Web-browser flow sheet of radiology reports. The rows all report one kind of study, and the columns report one date. Each cell shows the impression part of the radiology report as a quick summary of the content of that report. The cells include two icons. Clicking on the report icon provides the full radiology report. Clicking on the radiology image icon provides the images. (**b**) The chest X-ray images on radiology images obtained by clicking on the "bone" icon. What shows by default is a quarter-sized view of both the PA and lateral chest view X-ray. By clicking on various options, users can obtain up to the full (2,000×2,300) resolution, and window and level the images over the 12 bits of a radiographic image, using a control provided by Medical Informatics Engineering (MIE), Fort Wayne Indiana (Source: Courtesy of Regenstrief Institute, Indianapolis, IN)

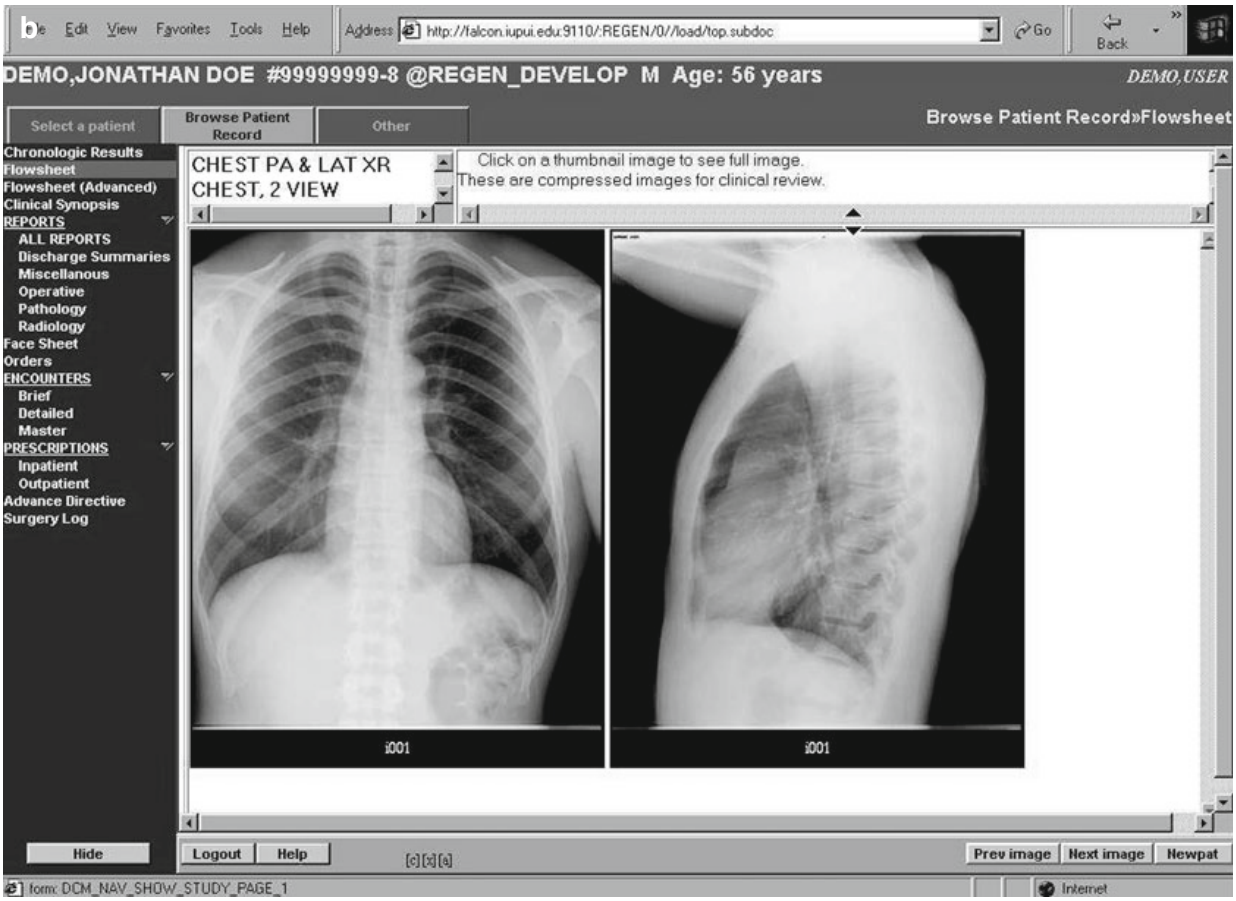

Fig. 12.13 (continued)

and patient safety professionals, and administrators can use these capabilities to analyze patient outcomes and practice patterns. Public health professionals can use the reporting functions of computer-stored records for surveillance, looking for emergence of new diseases or other health threats that warrant medical attention.

Although these functions of decision support on the one hand, and query surveillance systems, on the other, are different, their internal logic is similar. In both, the central procedure is to find records of patients that satisfy pre-specified criteria and export selected data when the patient meets those criteria. Surveillance queries generally address a large subset, or all, of a patient population; the output is often a tabular report of selected raw data on all the patient records retrieved or a statistical summary of the values contained in the records. Decision support generally addresses only those patients under active care; its output is an **alert** or **reminder message** (McDonald 1976). Query and surveillance systems can be used for clinical care, clinical research, retrospective studies, and administration.

12.4.3.1 Clinical Care

A query can also identify patients who are due for periodic screening examinations such as immunizations, mammograms, and cervical Pap tests and can be used to generate letters to patients or call lists for office staff to encourage the preventive care. Query systems are particularly useful for conducting ad hoc searches such as those required to identify and notify patients who have been receiving a recalled drug. Such systems can also facilitate quality management and patient safety activities. They can identify candidate patients for concurrent review and can gather many of the data required to complete such audits.

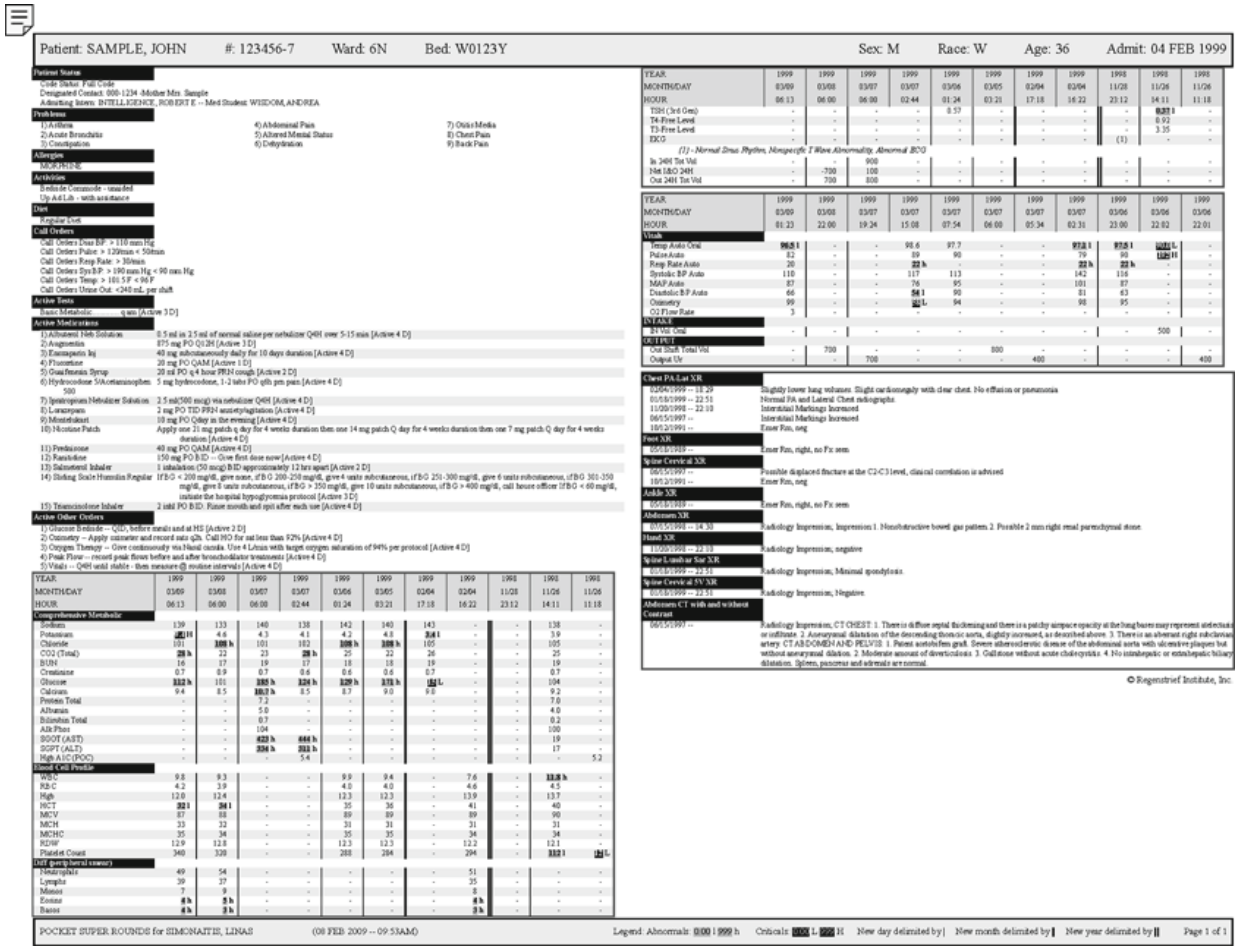

Fig. 12.14 The Pocket rounds report—so called because when folded from top to bottom, it fits in the clinician's white coat pocket as a booklet. It is a dense report (12 lines per inch, 36 characters per inch), printed in landscape mode on one 8 1/2×11 in. page), and includes the all active orders (including medications), recent laboratory results, vital signs and the summary impressions of radiology, endoscopy, and cardiology reports (Source: Courtesy of L. Simonaitis, Regenstrief Institute, Indianapolis, IN)

12.4.3.2 Clinical Research

Query systems can be used to identify patients who meet eligibility requirements for prospective clinical trials. For example, an investigator could identify all patients seen in a medical clinic who have a specific diagnosis and meet eligibility requirements while not having any exclusionary conditions. These approaches can also be applied in real time. At one institution, the physician's work station was programmed to ask permission to invite the patient into a study, when that physician entered a problem that suggested the patient might be a candidate for a local clinical trial. If the physician gave permission, the computer would send an electronic page to the nurse recruiter who would then invite the patient to participate in the study. It was first applied to a study of back pain (Damush et al. 2002).

12.4.3.3 Quality Reporting

Query systems can also play an important role in producing quality reports that are used for both internal quality improvement activities and for external public reporting. And, although it would be difficult for paper-based records to incorporate patient-generated input, and would require careful tagging of data source, an EHR could include data contributed by patients (e.g., functional status, pain scores, symptom reports). These patient-reported data may be incorporated in future quality measures. With the changing reimbursement payment models focusing more on outcomes measures instead of volume of transactions, generating efficient and timely reports of clinical quality measures will play an increasingly important role in management and payment.

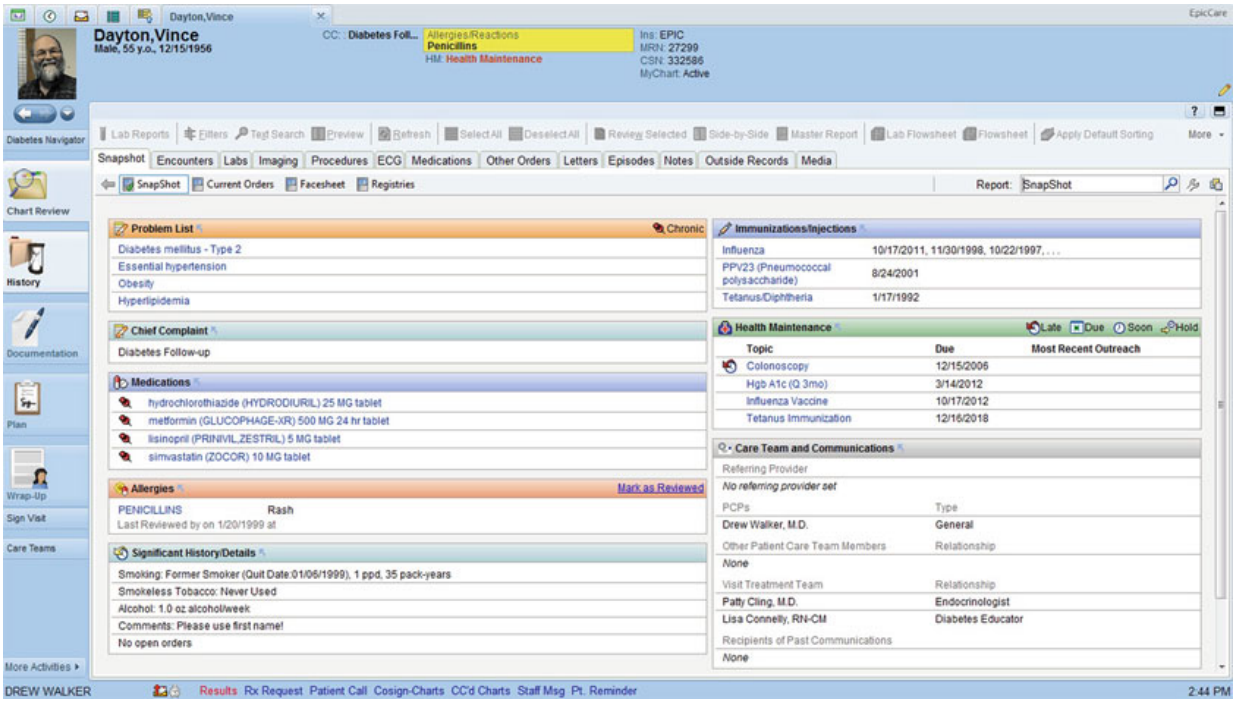

Fig. 12.15 Summary record. The patient's active medical problems, current medications, and drug allergies are among the core data that physicians must keep in mind when making any decision on patient care. This one-page screen provides an instant display of core clinical data elements as well as reminders about required preventive care. (Source: Courtesy of Epic Systems, Madison, WI)

12.4.3.4 Retrospective Studies

Randomized **prospective studies** are the gold standard for clinical investigations, but **retrospective studies** of existing data have contributed much to medical progress (See Chap. 11). Retrospective studies can obtain answers at a small fraction of the time and cost of comparable prospective studies.

EHR systems can provide many of the data required for a retrospective study. They can, for example, identify study cases and comparable control cases, and provide data needed for statistical analysis of the comparison cases (Brownstein et al. 2007). Combined with access to discarded specimens, they also offer powerful approaches to retrospective genome association studies that can be accomplished much faster and at cost magnitudes lower than comparable prospective studies (Kohane 2011; Roden et al. 2008).

Computer-stored records do not eliminate all the work required to complete an epidemiologic study; chart reviews and patient interviews may still be necessary. Computer-stored records are likely to be most complete and accurate with respect to drugs administered, laboratory test results, and visit diagnoses, especially if the first two types of data are entered directly from automated laboratory and pharmacy systems. Consequently, computer-stored records are most likely to contribute to research on a physician's practice patterns, on the efficacy of tests and treatments, and on the toxicity of drugs. However, NLP techniques make the content of narrative text more accessible to automatic searches (see Chap. 8).

12.4.3.5 Administration

In the past, administrators had to rely on data from billing systems to understand practice patterns and resource utilization. However, claims data can be unreliable for understanding clinical practice because the source data are coarse and often entered by non-clinical personnel not directly involved with the care decisions. Furthermore, relying on claims data as proxies for clinical diagnoses can produce inaccurate information and lead to inappropriate policymaking (Tang et al. 2007). Medical query systems in

conjunction with administrative systems can provide information about the relationships among diagnoses, indices of severity of illness, and resource consumption. Thus, query systems are important tools for administrators who wish to make informed decisions in the increasingly cost-sensitive world of health care. On the other hand, the use of EHR data for billing and administration can produce incentives for clinicians to steer their documentation to optimize payment and resource allocation, potentially making that documentation less clinically accurate. It may therefore be best to base financial decisions on variables that are not open to interpretation.

12.5 Challenges Ahead

Although many commercial products are labeled as EHR systems, they do not all satisfy the criteria that we defined at the beginning of this chapter. Even beyond matters of definition, however, it is important to recognize that the concept of an EHR is neither unified nor static. As the capability of technology evolves, the function of the EHR will expand. Greater involvement of patients in their own care, for example, means that **personal health records** (**PHRs**) should incorporate data captured at home and also support two-way communication between patients and their health care team (see also Chap. 17). The potential for patient-entered data includes history, symptoms, and outcomes entered by patients as well as data uploaded automatically by home monitoring devices such as scales, blood pressure monitors, glucose meters, and pulmonary function devices. By integrating these patient-generated data into the EHR, either by uploading the data into the EHR or by linking the EHR and the PHR, a number of long-term objectives can be achieved: patient-generated data may in some circumstances be more accurate or complete, the time spent entering data during an office visit by both the provider and the patient may be reduced, and the information may allow the production of outcomes measures that are better attuned to patients' goals. One caveat in this vision is the perception that this may lead to a deluge of data that the provider will never have time to sort through yet will be legally responsible for. A review of current products would be obsolete by the time that it was published. We have included examples from various systems in this chapter, both developed by their users and commercially available, to illustrate a portion of the functionality of EHR systems currently in use.

The future of EHR systems depends on both technical and nontechnical considerations. Hardware technology will continue to advance, with processing power doubling every 2 years according to Moore's law (see Chap. 1). Software will improve with more powerful applications, better user interfaces, and more integrated decision support. New kinds of software that support collaboration will continue to improve; social media are growing rapidly both inside and outside of health care. For example, as both providers and patients engage increasingly in social media, new ways to capture data, share data, collaborate, and share expertise may emerge. Perhaps the greater need for leadership and action will be in the social and organizational foundations that must be laid if EHRs are to serve as the information infrastructure for health care. We touch briefly on these challenges in this final section.

12.5.1 Users' Information Needs

We discussed the importance of clinicians directly using the EHR system to achieve maximum benefit from computer-supported decision making. On the one hand, organizations that require providers to enter all of their order, notes, and data directly into the EHR will gain substantial operational efficiency. On the other hand, physicians will bear the time costs of entering this information and may lose efficiency. Some balance between the organization's and providers' interests must be found. This balance is easiest to reach when physicians have a strong say in the decision.

Developers of EHR systems must thoroughly understand clinicians' information needs and workflows in the various settings where health

care is delivered. The most successful systems have been developed either by clinicians or through close collaborations with practicing clinicians.

Studies of clinicians' information needs reveal that common questions that physicians ask concerning patient information (e.g., Is there evidence to support a specific patient diagnosis? Has a patient ever had a specific test? Has there been any follow up because of a particular laboratory test result?) are difficult to answer from the perusal of the paper-based chart (Tang et al. 1994b)). Regrettably, most clinical systems in use now cannot easily answer many of the common questions that clinicians ask. Developers of EHR systems must have a thorough grasp of users' needs and workflows if they are to produce systems that help health care providers to use these tools efficiently to deliver care effectively.

12.5.2 Usability

An intuitive and efficient user interface is an important part of the system. Designers must understand the cognitive aspects of the human and computer interaction and the professional workflow if they are to build interfaces that are easy-to-learn and easy-to-use (see Chap. 4). Improving human–computer interfaces will require changes not only in how the system behaves but also in how humans interact with the system. User interface requirements of clinicians entering patient data are different from the user interfaces developed for clerks entering patient charges. Usability for clinicians means fast computer response times, and the fewest possible data input fields. *A system that is slow or requires too much input is not usable by clinicians*. The menus and vocabularies that constrain user input must include synonyms for all the ways health professionals name the items in the vocabularies and menus, and the system must have keyboard options for all inputs and actions because switching from mouse to keyboard steals user time. To facilitate use by busy health care professionals, health care applications developers must focus on clinicians' unique information needs. What information the provider needs and what tasks the provider performs should influence what and how information is presented. Development of human-interface technology that matches the data-processing power of computers with the cognitive capability of human beings to formulate insightful questions and to interpret data is still a rate-limiting step (Tang and Patel 1994). For example, one can imagine an interface in which speech input, typed narrative, and mouse-based structured data entry are accepted and seamlessly stored into a single data structure within the EHR, with a hybrid user display that shows both a narrative version of the information and a structured version of the same information that highlights missing fields or inconsistent values.

12.5.3 Standards

We alluded to the importance of standards earlier in this chapter, when we discussed the architectural requirements of integrating data from multiple sources. Standards are the focus of Chap. 7. Here, we stress the critical importance of national standards in the development, implementation, and use of EHR systems (Miller and Gardner 1997b). Health information should follow patients as they interact with different providers in different care settings. Uniform standards are essential for systems to interoperate and exchange data in meaningful ways. Having standards reduces development costs, increases integration, and facilitates the collection of meaningful aggregate data for quality improvement and health policy development. The HIPAA legislation has mandated standards for administrative messages, privacy, security, and clinical data. Regulations based on this legislation have already been promulgated for the first three of these categories.[18] Incentives provided by the HITECH Act (see Chaps. 7 and 27) stimulated a number of efforts including a report by the ONC

[18] http://www.hhs.gov/ocr/privacy/hipaa/administrative/index.html (Accessed 1/2/2012).

HIT Standards Committee (Health IT Standards Committee 2011) and Meaningful Use 2 (MU2) federal regulations (Final Rules: CMS 2012; Final Rule: ONC 2012) defining message and vocabulary standards for clinical data and encouraging EHR vendors and users to adopt them (see Sect. 12.3.1).[19] The US Department of Health and Human Services (HHS) maintains the current status of its HITECH programs on their Web site.[20]

12.5.4 Privacy and Security

Privacy and security policies and technology that protect individually identifiable health data are important foundational considerations for all applications that store and transmit and display health data. HIPAA established key regulations, and HITECH enhanced them, to protect the confidentiality of individually identifiable health information. With appropriate laws and policies computer-stored data can be more secure and confidential than those data maintained in paper-based records (Barrows and Clayton 1996).

12.5.5 Costs and Benefits

The Institute of Medicine (IOM) declared the EHR an essential infrastructure for the delivery of health care, and the protection of patient safety (IOM Committee on Improving the Patient Record 2001). Like any infrastructure project, the benefits specifically attributable to infrastructure are difficult to establish; an infrastructure plays an enabling role in all projects that take advantage of it. Early randomized controlled clinical studies showed that computer-based decision-support systems reduce costs and improve quality compared with usual care supported with a paper medical record (Tierney et al. 1993; Bates et al. 1997, 2003b; Classen et al. 1997), and recent meta-analyses of health information technology have demonstrated quality benefits (Buntin et al. 2011; Lau et al. 2010); however, Romano and Stafford (2011) did not find any "consistent association between EHRs and CDS and better quality."

Because of the significant resources needed and the significant broad-based potential benefits, the decision to implement an EHR system is a strategic one. Hence, the evaluation of the costs and benefits must consider the effects on the organization's strategic goals, as well as the objectives for individual health care (Samantaray et al. 2011). Recently, the federal government and professional organizations have both expressed interest in **Open Source** options for EHR software (Valdes 2008).

12.5.6 Leadership

Leaders from all segments of the health care industry must work together to articulate the needs, to define the standards, to fund the development, to implement the social change, and to write the laws to accelerate the development and routine use of EHR systems in health care. Because of the prominent role of the federal government in health care—as a payer, provider, policymaker, and regulator—federal leadership to create incentives for developing and adopting standards and for promoting the implementation and use of EHRs is crucial. Recently, Congress and the administration have acted to accelerate the adoption and meaningful use of health information technology based on some of the foundational research done in the informatics community (see Chap. 27). Technological change will continue to occur at a rapid pace, driven by consumer demand for entertainment, games, and business tools. Nurturing the use of information technology in health care requires leaders who promote the use of EHR systems and work to overcome the obstacles that impede widespread use of computers for the benefit of health care.

[19] http://www.healthit.gov/sites/default/files/standards-certification/HITSC_CQMWG_VTF_Transmit_090911.pdf (Accessed 1/3/2012).

[20] http://www.healthit.gov/policy-researchers-implementers/health-it-rules-regulations (Accessed 1/3/2012).

Suggested Readings

Barnett, G. O. (1984). The application of computer-based medical-record systems in ambulatory practice. *New England Journal of Medicine, 310*(25), 1643–1650. This seminal article compares the characteristics of manual and automated ambulatory patient record systems, discusses implementation issues, and predicts future developments in technology.

Bates, D. W., Kuperman, G. J., Wang, S., et al. (2003). Ten commandments for effective clinical decision support: Making the practice of evidence-based medicine a reality. *Journal of the American Medical Informatics Association, 10*(6), 523–530. The authors present ten very practical tips to designers and installers of clinical decision support systems.

Berner, E. S. (Ed.). (2010). *Clinical decision support systems, theory and practice: Health informatics series* (3rd ed.). New York: Springer. This text focuses on the design, evaluation, and application of Clinical Decision Support systems, and examines the impact of computer-based diagnostic tools both from the practitioner's and the patient's perspectives. It is designed for informatics specialists, teachers or students in health informatics, and clinicians.

Collen, M. F. (1995). *A history of medical informatics in the United States, 1950–1990*. Indianapolis: American Medical Informatics Association, Hartman Publishing. This rich history of medical informatics from the late 1960s to the late 1980s includes an extremely detailed set of references.

Gauld, R., & Goldfinch, S. (2006). *Dangerous enthusiasms: E-government, computer failure and information system development*. Dunedin: Otago University Press. Gauld and Goldfinch describe a number of large-scale **information and communications technology** (**ICT**) projects with an emphasis on health information systems, emphasizes the high failure rates of mega projects that assume they can create a design denovo, build from the design and deploy successfully. It also highlights the advantages of starting with more modest scopes and growing incrementally based on experience with the initial scope.

Institute of Medicine (IOM) Roundtable on Value and Science-Driven Health Care. (2011). *Digital infrastructure for the learning health system: The foundation for continuous improvement in health and health care – workshop series summary*. Washington, DC: National Academy Press. This report summarizes three workshops that presented new approaches to the construction of advanced medical record system that would gather the crucial data needed to improve the health care system.

Kuperman, G. J., Gardner, R. M., & Pryor, T. A. (1991). *The HELP system*. Berlin/Heidelberg: Springer-Verlag GmbH and Co. K. The HELP (Health Evaluation through Logical Processing) system was a computerized hospital information system developed by the authors at the LDS Hospital at the University of Utah, USA. It provided clinical, hospital administration and financial services through the use of a modular, integrated design. This book thoroughly documents the HELP system. Chapters discuss the use of the HELP system in intensive care units, the use of APACHE and APACHE II on the HELP system, various clinical applications and inactive or experimental HELP system modules. Although the HELP system has now been retired from routine use, it remains an important example of several key issues in EHR implementation and use that continue in the commercial systems of today.

Osheroff, J., Teich, J., Levick, D., et al. (2012). *Improving outcomes with clinical decision support: An implementers guide* (2nd ed.). Scottsdale: Scottsdale Institute, AMIA, AMDIS and SHM. This text provides guidance on using clinical decision support interventions to improve care delivery and outcomes in a hospital, health system or physician practice. The book also presents considerations for health IT software suppliers to effectively support their CDS implementer clients.

Walker, J. M., Bieber, E. J., & Richards, F. (2006). *Implementing an electronic health record system*. London: Springer. This book provides rich details, including the process plans, for implementing an EHR in a large provider setting. It is a great resource for anyone trying to learn about EHR deployments, covering topics related to preparation, support, and implementation.

Weed, L. L. (1969). *Medical records, medical evaluation and patient care: The problem-oriented record as a basic tool*. Chicago: Year Book Medical Publishers. In this classic book, Weed presents his plan for collecting and structuring patient data to produce a problem-oriented medical record.

Questions for Discussion

1. What is the definition of an EHR? What, then, is an EHR system? What are five advantages of an EHR over a paper-based record? Name three limitations of an EHR.
2. What are the five functional components of an EHR? Think of the information systems used in health care institutions in which you work or that you have seen. Which of the components that you named do those systems have? Which are missing? How do the missing elements limit the value to the clinicians or patients?

3. Discuss three ways in which a computer system can facilitate information transfer between hospitals and ambulatory care facilities, thus enhancing continuity of care for previously hospitalized patients who have been discharged and are now being followed up by their primary physicians.
4. Much of medical care today is practiced in teams, and coordinating the care delivered by teams is a major challenge. Thinking in terms of the EHR functional components, describe four ways that EHRs can facilitate care coordination. Describe two ways in which EHRs are likely to create additional challenges in care coordination.
5. How does the health care financing environment affect the use, costs, and benefits of an EHR system? How has the financing environment affected the functionality of information systems? How has it affected the user population?
6. Would a computer scan of a paper-based record be an EHR? What are two advantages and two limitations of this approach?
7. Among the key issues for designing an EHR system are what information should be captured and how it should be entered into the system. Physicians may enter data directly or may record data on a paper worksheet (encounter form) for later transcription by a data-entry worker. What are two advantages and two disadvantages of each method? Discuss the relative advantages and disadvantages of entry of free text instead of entry of fully coded information. Describe an intermediate or compromise method.
8. EHR data may be used in clinical research, quality improvement, and monitoring the health of populations. Describe three ways that the design of the EHR system may affect how the data may be used for other purposes.
9. Identify four locations where clinicians need access to the information contained in an EHR. What are the major costs or risks of providing access from each of these locations?
10. What are three important reasons to have physicians enter orders directly into an EHR system? What are three challenges in implementing such a system?
11. Consider the task of creating a summary report for clinical data collected over time and stored in an EHR system. Clinical laboratories traditionally provide summary test results in flowsheet format, thus highlighting clinically important changes over time. A medical record system that contains information for patients who have chronic diseases must present serial clinical observations, history information, and medications, as well as laboratory test results. Suggest a suitable format for presenting the information collected during a series of ambulatory-care patient visits.
12. The public demands that the confidentiality of patient data must be maintained in any patient record system. Describe three protections and auditing methods that can be applied to paper-based systems. Describe three technical and three nontechnical measures you would like to see applied to ensure the confidentiality of patient data in an EHR. How do the risks of privacy breaches differ for the two systems?

Health Information Infrastructure

13

William A. Yasnoff

After reading this chapter you should know the answers to these questions:

- What is the vision and purpose of Health Information Infrastructure (HII)?
- What kinds of impacts will HII have, and in what time periods?
- Why is architecture so crucial to HII success?
- What are the political and technical barriers to HII implementation?
- What are the desirable characteristics of HII evaluation measures?

13.1 Introduction

This chapter addresses **health information infrastructure** (**HII**), community level informatics systems designed to make comprehensive electronic patient records available when and where needed for the entire population. There are numerous difficult and highly interdependent challenges that HII systems must overcome, including privacy, stakeholder cooperation, assuring all-digital information, and providing financial sustainability. As a result, while HII has been pursued for years with myriad approaches in many countries, progress has been slow and no proven formula for success has yet been identified.

W.A. Yasnoff, MD, PhD
NHII Advisors, 1854 Clarendon Blvd.,
Arlington 22201, VA, USA
e-mail: william.yasnoff@nhiiadvisors.com

While the discussion here is focused on the development of the HII in the United States, many other countries are involved in similar activities and in fact have progressed further along this road. Canada, Australia, and a number of European nations have devoted considerable time and resources to their own national HIIs. The United Kingdom, for example, has spent several billion pounds over the last few years to upgrade substantially its health information system capabilities. It should be noted, however, that all of these nations have centralized, government-controlled health care systems. This organizational difference from the multifaceted, mainly private health care system in the U.S. results in a somewhat different set of issues and problems. One can hope that the lessons learned from HII development activities across the globe can be effectively shared to ease the difficulties of everyone who is working toward these important goals.

13.2 Vision and Benefits of HII

The vision of HII is comprehensive electronic patient information when and where needed, allowing providers to have complete and current information upon which to base clinical decisions. In addition, clinical decision support (see Chap. 22) would be integrated with information delivery. In this way, both clinicians and patients could receive reminders of the most recent **clinical guidelines** and research results. This would

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DOI 10.1007/978-1-4471-4474-8_13,

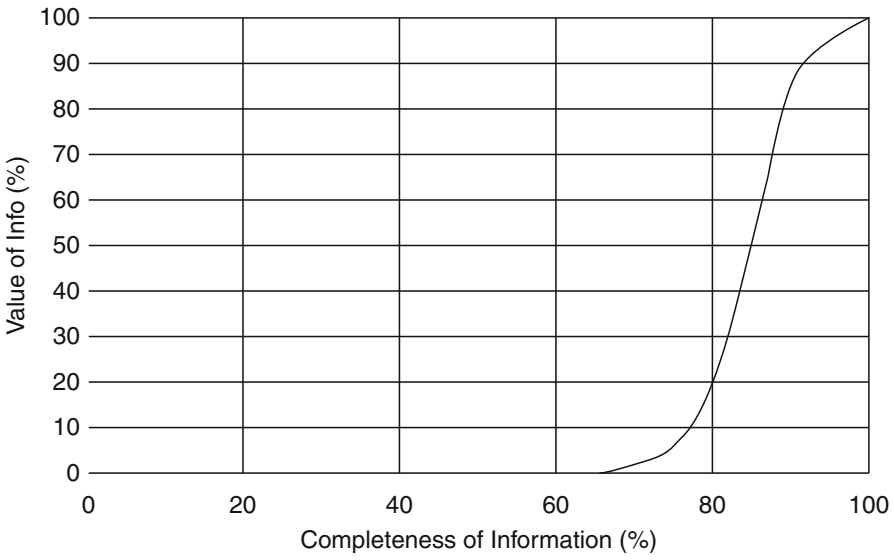

Fig. 13.1 Estimated value vs. completeness of health information. Medical information of any given type for a patient typically needs to be over 85 % complete before it starts being truly valuable to clinicians

avoid the need for clinicians to have superhuman memory capabilities to assure the effective practice of medicine, and enable patients more easily to adhere to complex treatment protocols and to be better informed. Patients could also review and add information to their record and thereby become more active participants in their care. In addition, the availability of comprehensive records for each patient would enable value-added services, such as immediate electronic notifications to patients' family members about emergency care, as well as authorized queries in support of medical research, public health, and public policy decisions.

In considering HII, it is extremely important to appreciate that medical information for a given patient must, in general, be relatively complete before it is truly valuable for clinical use (see Fig. 13.1). For example, if a physician has access to an electronic information system that can retrieve half of each patient's list of medications, it is unlikely such a system will be actively used. Knowing that the information is incomplete, the physician will still need to rely on other traditional sources of information to fill in the missing data (including questioning the patient). So there is little added benefit for investing the time to obtain the partial information from the new system. Similarly, applying clinical decision support to incomplete patient data may produce erroneous, misleading, or even potentially dangerous results. Therefore, HII systems must reliably provide reasonably complete information to be valuable to clinicians for patient care, and to make their use worthwhile.

The potential benefits of HII are both numerous and substantial. Perhaps most important are error reduction and improved quality of care. Many studies have shown that the complexity of present-day medical care results in very frequent errors of both omission and commission (Institute of Medicine 1999). The source of this problem was clearly articulated by Masys, who observed that current medical practice depends upon the "clinical decision-making capacity and reliability of autonomous practitioners for classes of problems that routinely exceed the bounds of unaided human cognition." (Masys 2002). Electronic health information systems can contribute significantly to alleviating this problem by reminding practitioners about recommended actions at the point of care. This can include both notifications of actions that may have been missed and warnings about planned treatments or procedures that may be harmful or unnecessary. Literally dozens of research studies have shown that such reminders improve safety and reduce costs (Bates 2000; Kass 2001). In one such study, medication errors were reduced by 55 % (Bates et al. 1998). Another study by the RAND Corporation showed that only 55 % of U.S. adults were receiving recommended care (McGlynn et al. 2003). The same techniques used to reduce medical errors with electronic health information systems also

contribute substantially to ensuring that recommended care is provided. This is becoming increasingly important as the population ages and the prevalence of chronic disease increases.

Guidelines and reminders also can improve the effectiveness of dissemination of new research results. At present, widespread application of a new research in the clinical setting takes an average of 17 years (Balas and Boren 2000). Patient-specific reminders delivered at the point of care, highlighting important new research results, could substantially accelerate this adoption rate.

Another important contribution of HII to the research domain is improving the efficiency of clinical trials. At present, most clinical trials require the creation of a unique information infrastructure to insure protocol compliance and to collect essential research data. With an effective HII, every practitioner would have access to a fully functional **electronic health record** (**EHR**), so clinical trials could routinely be implemented through the dissemination of guidelines that specify the research protocol. Data collection would occur automatically in the course of administering the protocol, reducing time and costs. In addition, there would be substantial value in analyzing **de-identified aggregate data** from routine patient care to assess the outcomes of various treatments, and monitor the health of the population.

Another critical function for HII is early detection of patterns of disease, particularly early detection of outbreaks from newly-virulent microorganisms or possible bioterrorism. Our current system of disease **surveillance**, which depends on alert clinicians diagnosing and reporting unusual conditions, is both slow and potentially unreliable. These problems are illustrated by delayed detection of the anthrax attacks in the Fall of 2001, when seven cases of cutaneous anthrax in the New York City area 2 weeks before the so-called "index" case in Florida went unreported (Lipton and Johnson 2001). Since all the patients were seen by different clinicians, the pattern could not have been evident to any of them even if the correct diagnosis had immediately been made in every case. Wagner et al. described nine categories of requirements for surveillance systems for potential bioterrorism outbreaks—several categories must have immediate electronic reporting to ensure early detection (Wagner et al. 2003).

HII would allow immediate electronic reporting of both relevant clinical events and laboratory results to public health (see Chap. 16). Not only would this be an invaluable aid in early detection of bioterrorism, it would also serve to improve the detection of the much more common naturally occurring disease outbreaks. In fact, early results from a number of electronic reporting demonstration projects show that disease outbreaks can routinely be detected sooner than was ever possible using the current system (Overhage et al. 2001). While early detection has been shown to be a key factor in reducing morbidity and mortality from bioterrorism (Kaufmann et al. 1997), it will also be extremely helpful in reducing the negative consequences from other disease outbreaks.

Finally, HII can substantially reduce health care costs. The inefficiencies and duplication in our present paper-based health care system are enormous. One study showed that the anticipated nationwide savings from implementing advanced **computerized physician order entry** (**CPOE**) systems in the outpatient environment would be $44 billion/year (Johnston et al. 2003), while a related study (Walker et al. 2004) estimated $78 billion more in savings from **health information exchange** (**HIE**) (for a total of $122 billion/year). Substantial additional savings are possible in the inpatient setting—numerous hospitals have reported large net savings from implementation of EHRs. Another example, electronic prescribing, would not only reduce medication errors from transcription, but also drastically decrease the administrative costs of transferring prescription information from provider offices to pharmacies. Another analysis concluded that the total efficiency and patient safety savings from HII would be in range of $142–371 billion each year (Hillestad et al. 2005), and a survey of the recent literature found predominantly positive benefits from HII (Buntin et al. 2011). It is important to note that much of the savings depends not just on

the widespread implementation of EHRs, but the effective interchange of this information to insure that the complete medical record for every patient is immediately available in every care setting.

Inasmuch as the current cost trend of health care is unsustainable, particularly in the face of our aging population, this issue is both important and urgent. Without comprehensive electronic information, any health care reform is largely guesswork in our current "black box" health care environment where the results of interventions often take years to understand. We do not currently have mechanisms for timely monitoring of health care outcomes to inform needed course corrections in any proposed reform. In essence, health care must be "informed" before it can be "reformed."

13.3 History

In the U.S., the first major report to address HII was issued by the Institute of Medicine of the National Academy of Sciences in 1991 (IOM 1991). This report, "The Computer-Based Patient Record," was the first in a series of national expert panel reports recommending transformation of the health care system from reliance on paper to electronic information management (see Chap. 12). In response to the IOM report, the Computer-based Patient Record Institute (CPRI), a private not-for-profit corporation, was formed for the purpose of facilitating the transition to computer-based records. A number of **community health information networks** (**CHINs**) were established around the country in an effort to coalesce the multiple community stakeholders in common efforts towards electronic information exchange. The Institute of Medicine updated its original report in 1997 (IOM 1997), again emphasizing the urgency to apply information technology to the information intensive field of health care.

However, most of the CHINs were not successful. Perhaps the primary reason for this was that the standards and technology were not yet ready for cost-effective community-based electronic HIE. Another problem was the focus on availability of aggregated health information for secondary uses (e.g., policy development), rather than individual information for the direct provision of patient care. Also, there was neither a sense of extreme urgency nor were there substantial funds available to pursue these endeavors. However, at least one community (Indianapolis, Indiana) continued to move forward throughout this period and has now emerged as an a national example of the application of information technology to health care both in individual health care settings and throughout the community (McDonald et al. 2005).

Widespread attention was focused on this issue with the IOM report "To Err is Human" (IOM 1999). This landmark study documented the accumulated evidence of the high error rate in the medical care system, including an estimated 44,000–98,000 preventable deaths each year in hospitals alone. It has proven to be a milestone in terms of public awareness of the negative consequences of paper-based information management in health care. Along with the follow-up report, "Crossing the Quality Chasm" (IOM 2001), the systematic inability of the health care system to operate at a high degree of reliability has been thoroughly elucidated. These reports clearly place the blame on the system, not on the dedicated health care professionals who work in an environment without effective tools to promote quality and to minimize errors.

Several additional national expert panel reports have emphasized the IOM findings. In 2001, the President's Information Technology Advisory Committee (PITAC) issued a report entitled "Transforming Health Care Through Information Technology" (PITAC 2001). That same year, the Computer Science and Telecommunications Board of the National Research Council (NRC) released "Networking Health: Prescriptions for the Internet" (NRC 2001), which emphasized the potential for using the Internet to improve electronic exchange of health care information. Finally, the National Committee on Vital and Health Statistics (NCVHS) outlined a vision for building a National HII in its report, "Information for Health" (NCVHS 2001). NCVHS, a statutory advisory body to the U.S.

Department of Health and Human Services (DHHS), indicated that Federal government leadership was needed to facilitate further development of HII. In response, DHHS began an HII initiative, organizing a large national conference in 2003 to develop a consensus agenda to guide progress (DHHS 2003; Yasnoff et al. 2004).

In April, 2004, a Presidential Executive Order created the Office of the National Coordinator for Health Information Technology (ONC) in DHHS (see also Chap. 27). The initial efforts of ONC focused on promoting standards and certification to support adoption of EHRs by physicians and hospitals. It also promoted implementation of an "institution centric" model for HIE by **Regional Health Information Organizations** (**RHIOs**), wherein electronic records for a given patient stored at sites of past care episodes are located, assembled, and delivered in real time when needed for patient care. Four demonstration projects implementing this model were funded, but did not lead to sustainable systems.

In 2008, ONC was codified in law by the Health Information Technology for Economic and Clinical Health (HITECH) portion of the ARRA statute (Chap. 27). In addition, $20+ billion was appropriated including $2 billion for ONC and the remainder for payment of EHR incentives through Medicare and Medicaid to providers who achieve "Meaningful Use" of these systems. The ONC used its resources to establish **regional extension centers** (**RECs**) to subsidize assistance to providers adopting and using EHRs ($677 million), fund states to establish HIEs ($564 million), and initiate several research programs.

In December, 2010, the President's Council of Advisors on Science and Technology (PCAST) issued a report expressing concern about ONC strategy, specifically indicating that its HIE efforts through the states "*will not solve the fundamental need for data to be universally accessed, integrated, and understood while also being protected*" (PCAST 2010). Findings of a recent survey of HIEs "*call into question whether RHIOs in their current form can be self-sustaining and effective*"(Adler-Milstein et al. 2011). It is clear that more than two decades after the 1991 IOM report urging universal adoption of EHRs, the U.S. still lacks a clear and feasible roadmap leading to the widespread availability of comprehensive electronic patient information when and where needed. Despite much progress, no one in the U.S. as yet receives their medical care with the assured, immediate availability of all their records across multiple providers and provider organizations.

13.4 Requirements for HII

As with any informatics system development project, it is critical at the outset to understand the desired end result. In the case of a large, extremely complex system such as HII, this is especially important because there are many stakeholders with conflicting incentives and agendas, as well as challenging policy and operational issues. The ultimate goal is the "availability of comprehensive electronic patient records when and where needed." In transforming this goal into a design specification, it is critical to understand the issues and constraints that must be addressed. Then any proposed system design must demonstrate (on paper) how the objectives will be achieved within those limitations.

13.4.1 Privacy and Trust

The most important and overriding requirement of HII is privacy. Clearly, health records are very sensitive – perhaps the most sensitive personal information that exists. In addition to our natural desire to keep our medical information private, improper disclosure can lead to employment discrimination. Furthermore, failure to assure the privacy of records will naturally result in patient unwillingness to disclose important personal details to their providers – or even to avoid seeking care at all. In addition to the contents of the records, the very existence of certain records (e.g., a visit to psychiatric hospital) is sensitive even if no details are available. Therefore, extraordinary care must be taken to ensure that information is protected from unauthorized disclosure and use.

In general, U.S. Federal law (the HIPAA Privacy Rule as introduced in Chap. 10) requires patient consent for disclosure and use of medical records. However, consent is not required for record release for treatment, payment, and health care operations. These "TPO" exceptions have, as a practical matter, allowed health care organizations to utilize medical records extensively while bypassing patient consent. The organization that holds medical information has sole discretion to make the decision whether a proposed disclosure is or is not a TPO exception. Until recently, TPO disclosures did not even need to be recorded, effectively preventing discovery of improper disclosures. Even under the recent HITECH legislation that requires records of TPO disclosures, such records are not automatically available to the subjects of the disclosures. The net effect is that individuals not only lack control over the dissemination of their medical records, but are not even informed when they are disclosed beyond where they were created.

It seems appropriate to question whether this disclosure regime is adequate for electronic health records. The general public understands that making electronic patient records available for good and laudable purposes simultaneously makes them more available for evil and nefarious purposes, thereby necessitating higher levels of protection to avoid abuses. Assigning decision-making for disclosure of personal medical records to anyone other than the patient or the patient's representative inherently erodes trust. In essence, the patient is being told, "we are going to decide for you where your medical records should go because we know what's in your interest better than you do." Patients may wonder why, if a given disclosure is in their interest, their consent would not be sought. Furthermore, failing to seek such consent inevitably leads to suspicion that the disclosure is in fact not in the patient's interest, but rather in the interest of the organization deciding that the records should be released.

The concern about privacy of medical records is not at all theoretical or insignificant. In two recent consumer surveys, 13–17 % of consumers indicated that they already employ "information hiding" behaviors with respect to their medical records (CHCF 2005; Harris Interactive 2007). This includes activities such as obtaining laboratory tests under an assumed name or seeking out-of-state treatment to conceal an illness from their primary care provider. Even assuming that everyone engaged in such behaviors was willing to admit to them in such a survey, this represents a substantial proportion of consumers who would, at a minimum, refuse to participate in an electronic medical information system that did not provide them with control over their own records. Of even greater concern, such a large percentage of consumers would likely organize and use their political power to halt the deployment and operation of such a system. Indeed, it was a much smaller percentage of concerned citizens that, citing the threat to privacy, convinced Congress to repeal the provisions in the original HIPAA legislation calling for a unique medical identifier for all U.S. residents (see Chap. 10).

In view of this, there are those who argue that all decisions about release of patient records need to be entrusted to the patient (with rare exceptions, such as mental incompetence). They also suggest that attention to these concerns may be especially important for enabling HII, because patients must trust that their records are not being misused in such a system. Some argue that patients are not sufficiently informed to make such decisions and may make mistakes that are harmful to them, whereas others believe that the negative consequences of delegating this decision-making to others than the patient could be much greater. Advocates of patient control of medical information argue, by analogy, that society has accepted that individuals retain the right to make decisions about how their own money is spent, even though this can lead to adverse consequences when those decisions prove to be unwise. In considering these issues, it should be noted that prior to the 2002 HIPAA Privacy Rule that established the TPO exceptions, both law and practice had always required patient consent for all access to medical records. While acknowledging the need for consumer education about decisions relating to release of medical records, patient-control advocates believe that the same freedom and personal responsibility that applies

to an individual's financial decisions may need to be applied to the medical records domain. These medical information privacy policy issues may be even more urgent in the context of the enhanced trust necessary when seeking to implement an effective and accepted HII.

13.4.2 Stakeholder Cooperation

To ensure the availability of comprehensive patient records, all health care stakeholders that generate such records must consistently make them available. While it would be ideal if such cooperation were voluntary, assuring long-term collaboration of competing health care stakeholders is problematic. Indeed, only a handful of communities have succeeded in developing and maintaining an organization that includes the active participation of the majority of health care providers. Even in these communities, the system could be disrupted at any time by the arbitrary withdrawal of one or more participants. The unfortunate reality is that health care stakeholders are often quite reluctant to share patient records, fearing loss of competitive advantage.

Therefore, some would argue that mandating health care stakeholder participation in a system for sharing electronic patient records is highly desirable, since it would result in consistently more comprehensive individual records. Since imposing a new requirement on health care stakeholders would be a daunting political challenge, such an approach would be most feasible as part of an existing mandate. Proponents of this approach have noted that one such mandate that could be utilized is the HIPAA Privacy Rule itself, which requires all providers to respond to patient requests for their own records (U.S. 45 CFR 164.524(a)). Furthermore, if patients request their records in electronic form, and they are available in electronic form, this regulation also requires that they be delivered in electronic form. Although not well known, this latter provision is included in the original HIPAA Privacy Rule (U.S. 45 CFR 164.524(c)(2)), and has been reinforced by HITECH. It is also being promoted by the more recent "blue button" initiative that seeks to allow patients to retrieve their own records electronically (Chopra et al. 2010).

Advocates argue that patient control, in addition to being an effective approach to privacy, could also serve to ensure ongoing, consistent health care stakeholder participation. Of course, in order for this approach to be practical, the rights of patients to electronic copies of their records under HIPAA would need to be enforced. Such enforcement has to date been inconsistent, and, until recently, exclusively dependent on the Office of Civil Rights at DHHS (since patients do not have a private right of action). Under HITECH, state attorneys general may also bring legal action, which may be helpful in improving compliance.

13.4.3 Ensuring Information in Electronic Form

It is self-evident that the electronic exchange of health information cannot occur if the information itself is not in electronic form. While medication information and laboratory results are already predominantly electronic, patient records, particularly for office-based physicians, are not. While estimates vary, it is clear that the majority of office-based physicians still do not utilize EHR systems, even though there is a major effort to incentivize the adoption of such records (see Chaps. 12 and 27). Furthermore most of those who do have electronic records utilize systems with limited capabilities (DesRoches et al. 2008).

The major obstacle for physician adoption of EHRs is not merely cost, as is often cited, but the very unfavorable ongoing cost/benefit ratio. Most of the benefits of EHRs in physician offices accrue not to the physician, but to other stakeholders. In one study, 89 % of the economic benefit was attributed to other stakeholders (Hersh 2004). It is unreasonable to expect physicians to shoulder 100 % of the cost of systems while accruing only 11 % of the benefits.

While the substantial physician subsidies in HITECH ($44,000–$63,750) are helpful (Chap. 27),

they do not cover the majority of costs for physician EHR systems. This is particularly evident when including the substantial conversion costs related to reduced revenue from lost productivity during the transition from paper to electronic records. In addition, the HITECH subsidies are one time only, while the costs of EHRs continue indefinitely for physicians. To assure EHR adoption by the vast majority of practices, many observers believe it will be necessary to provide permanent reimbursement and/or other offsetting benefits to allow physicians to recoup their costs. At the very least, any proposed approach to building a sustainable HII will be more effective if it includes mechanisms that result in a favorable cost/benefit ratio for physician EHRs.

As for hospitals, they also have not uniformly adopted EHRs. However, hospitals have a more substantial economic incentive to do so, since reducing their costs improves financial performance under the **diagnosis-related groups** (**DRG**) reimbursement system that pays a fixed amount for a specific condition. While it remains to be seen if the HITECH incentives for hospitals are sufficient to induce widespread adoption, it appears that their effectiveness will be substantially greater than for office-based physicians. In addition, once patients are admitted to the hospital, coordinating their records is largely an internal problem that cannot be greatly aided by external HII. Furthermore, the large majority of health care encounters do not involve hospitals, and therefore HII should focus primarily on the outpatient environment.

It is important to note that EHRs alone, even if adopted by all health care providers, are a necessary but not sufficient condition for achieving HII. Indeed, each EHR simply converts an existing paper "silo" of information to electronic form. These provider-based systems manage the *provider* information on the patient in question, but do not have *all* the information for each patient. To achieve the goal of availability of comprehensive patient information, there must also be an efficient and cost-effective mechanism to aggregate the scattered records of each patient from all their various providers. Major gains in quality and efficiency of care will be attainable only through HII that ensures the availability of every patient's comprehensive record when and where needed.

13.4.4 Financial Sustainability

There are three fundamental approaches that can be used individually or in combination to provide long-term financial sustainability for HII: (1) public subsidy; (2) leveraging anticipated future health care cost savings; or (3) leveraging new value created. The first approach has been advocated by those who assert, with some justification, that HII represents a public good that benefits everyone. They compare HII to other publicly available infrastructure, such as roads, and suggest that taxation is an appropriate funding mechanism. Of course, new taxes are consistently unpopular and politically undesirable, and other key infrastructures such as public utilities and the Internet, although regulated, are funded through user fees rather than taxation. Note, however, that at least two states (Maryland and Vermont) are using this mechanism to help fund their HII.

The most common approach suggested for long-term HII sustainability is leveraging anticipated health care cost savings. This is based on the substantial and growing body of evidence that the availability of more comprehensive electronic patient records to providers results in higher quality and lower cost care (AHRQ 2006; Buntin et al. 2011). Some of the best examples include large, mostly closed health care systems such as Kaiser, Group Health and the Veterans Administration, where the conversion of records into electronic form over time has been consistently associated with both cost savings and better care. While the case for HII reducing health care costs is compelling, the distribution and timing of those savings is difficult to predict. In addition, cost savings to the health care system means revenue losses to one or more stakeholders – clearly an undesirable result from their perspective. Finally, the allocation of savings for a given population of patients is unknown, with the result that organizations are reluctant to make specific

financial commitments that could be larger than their own expected benefits.

The final but least frequently mentioned path to financial sustainability of HII is utilizing the new value created by the availability of comprehensive electronic information. While it is widely recognized that this information will be extremely valuable for a wide variety of purposes, this option has remained largely unexplored. One example of such new value is the potential reduction in cost for delivering laboratory results to ordering physicians. The expenses borne by individual laboratories for their own infrastructure providing this essential service can be greatly reduced by a single uniform community infrastructure providing electronic delivery to physicians through one mechanism. Another example is availability of medical information for research – both to find eligible subjects for clinical trials and to utilize the data itself for research queries. While this latter application has the potential to defray a substantial portion of the costs of HII, it requires efficient mechanisms for both searching data and recording and maintaining patient consent that have not generally been incorporated into HII systems.

Perhaps the most lucrative HII revenue source lies in the development of innovative applications that rely on the underlying information to deliver compelling value to consumers and other health care stakeholders. For example, HII allows the delivery of timely and accurate reminders and alerts to patients for recommended preventive services, needed medication refills, and other medically related events of immediate interest to patients and their families. It also would allow deployment of applications that assist consumers automatically with management of their chronic diseases. Microsoft recognized and identified such an "application ecosystem" as the ultimate business model that could support HII when it introduced its HealthVault™ personal health record system (Microsoft 2012). Utilizing new value to finance HII avoids the prediction and allocation problems inherent in attempts to leverage expected health care cost savings, with the added incentive that any such savings would fully accrue to whoever achieves them.

13.4.5 Community Focus

Most observers believe that successful HII must be focused on the community. An essential element in HII is trust, which is inherently local. Furthermore, health care itself is predominantly local, since the vast majority of medical care for residents of a given community is provided in that community. Indeed, people traveling away from home who are injured or become ill inevitably will return home at their earliest opportunity if their condition permits (and does not resolve quickly). Since medical care is predominantly local, creating a system that delivers comprehensive electronic patient information in a community solves the overwhelming majority of information needs in that community. While movement of health information over long distances has some value and ultimately must be addressed to assure completeness of records, its contribution to a total solution is marginal.

The lack of any examples of working HII in communities larger than about ten million people provides additional evidence of the need for local focus. Keeping the scope of such projects relatively small also increases their likelihood of success by reducing complexity, thereby avoiding the huge increases in failure rates of extremely large-scale IT projects. For example, the need for local focus was a key part in planning for HII in the U.K., which was divided into five regions of approximately 12 million people in an attempt to facilitate addressing HII development through multiple systems, each working at a feasible scale (Granger 2004).

In thinking about HII, analogies are often made to the international financial system that efficiently transfers and makes funds available to individuals anywhere in the world. However, it is often forgotten that these financial institutions, that also are heavily dependent on trust, began as "building and loan funds" in small communities designed to share financial resources among close neighbors. It took many decades of building trust before large-scale national and international financial institutions emerged.

13.4.6 Governance and Organizational Issues

Trust is arguably the most important element in considering the appropriate governance for HII. Even in a system where patients exert full control over their own records, the organization that operates the HII must earn the full faith and confidence of consumers for the security, integrity, and protection of the records, as well as ensuring that records are appropriately available for purposes that consumers specify. Furthermore, the organization ideally must be devoid of any biases or hidden agendas that would favor one category of health care stakeholders over another, or favor specific stakeholders within a given category.

None of the existing health care stakeholders seem well suited to meet the trust requirement. Many argue that government cannot operate an HII because it is inherently not trusted with sensitive personal records, and furthermore needs to assume the role of providing regulatory oversight for whatever organization does take the HII responsibility. Similarly, it seems problematic for employers to be responsible for the HII since one of the primary concerns of consumers is to avoid disclosing sensitive medical information to their employers. Health plans and insurers are typically not trusted by consumers because their incentives are not aligned–they have a financial incentive to deny care, which is a natural concern to consumers. Hospitals are in competition with each other and therefore are not in a good position to cooperate in a long-term HII effort. Physicians are the most trusted health care stakeholders, from a consumer perspective, but are not organized in a way to facilitate the creation of HII. Furthermore, they are also in competition with each other and, most importantly, do not generally have the informatics capabilities necessary for such a complex endeavor.

Therefore, many believe that an independent (perhaps entirely new) organization is needed to operate HII in communities. This organization would have no direct connections to existing health care stakeholders and therefore would be unbiased. Its sole function would be to protect and make available comprehensive electronic patient records on behalf of consumers. Such an independent organization would also ideally facilitate cooperation among all existing stakeholders, who would know that the HII activity was completely neutral and designed primarily to serve consumers.

13.5 Architecture for HII

13.5.1 Institution-Centric Architecture

With rare exceptions, most existing HII systems have chosen an institution-centric approach to data storage, leaving patient records wherever they are created (Fig. 13.2). Although records are not stored centrally, there is a need to maintain at least a central index of where information can be found for a particular patient; without such an index, finding information about each patient would require queries to every possible source of medical information worldwide – clearly an impractical approach. When a given patient's record is requested, the index is used to generate queries to the locations where information is stored. The responses to those queries are then aggregated (in real time) to produce the patient's complete record. After the patient encounter, the new data is entered into the clinician's EHR system and another pointer (to that system) is added to the index so it will be queried (in addition to all the other prior locations) next time that patient's record is requested.

While this architecture is appealing to health care stakeholders because they continue to "control" the records they generate, one can argue that it fails to meet several key requirements, does not scale effectively, and is complex and expensive to operate. The most critical requirement that is not addressed by this architecture is searching the data, e.g., to find all patients with a cholesterol level above 300. To do such a search, the records of every patient must be assembled from their various locations and examined one at a time. This is known as a sequential search, and has a very long completion time that increases linearly

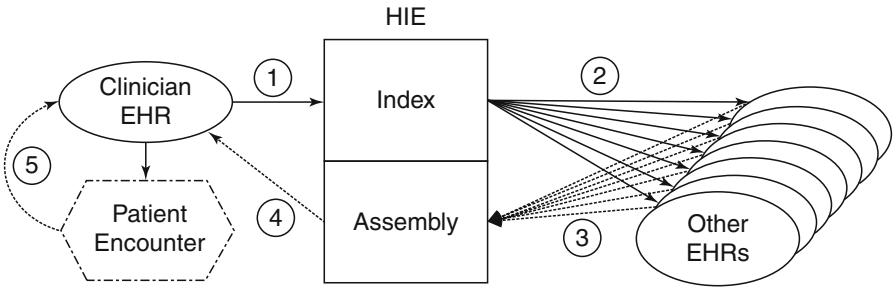

Fig. 13.2 Institution-centric HII architecture. *1*. The clinician EHR requests prior patient records from the HIE; this clinician's EHR is added to the index for future queries for this patient (if not already present). *2*. Queries are sent to EHRs at all sites of prior care recorded in the HIE index. *3*. EHRs at each prior site of care return records for that patient to the HIE; the HIE must wait for all responses. *4*. The returned records are assembled and sent to the clinician EHR; any inconsistencies or incompatibilities between records must be resolved in real time. *5*. After the care episode, the new information is stored in the clinician EHR only (© Health Record Banking Alliance, 2013. Used with permission)

with the size of the population. For example, in a modest-sized HIE with 500,000 patients, assuming retrieval and processing of each patient's records requires just 2 s (a very low estimate), each such search would take at least 12 days (1 million seconds). Furthermore, every such search would require that each provider record system connected to the HIE retrieve and transmit all its information – a very substantial computing and communications burden (that also increases the risk of interception of information). In standard database systems, impractical sequential search times are reduced by pre-indexing the contents of the records. However, such pre-indexing would in essence create a central repository of indices that could be used to reconstruct most of the original data, and therefore is inconsistent with this architectural approach.

It may be argued that the searches could themselves be distributed to the provider systems, and then the results aggregated into a coherent result. However, this approach also fails for this architecture because individual patient records are incomplete in each system. Therefore, searches that require multiple items of patient data (e.g., patients with chest pain who have taken a certain medication in the past year), will produce anomalous results unless all the instances of the relevant data for a given patient are in a single provider system (i.e., if one system finds a patient with chest pain, but without any indication of the medication of interest [which is in another provider's system], that patient will not be reported as satisfying the conditions). It is possible to limit searches to a single criterion and then combine the results from each such search to generate a correct result. However, this would mean that such searches would require multiples of the completion time for a single criterion (e.g., 12 days $\times 2 = 24$ days for the two criteria example), making the retrieval times and processing burdens even more untenable.

In addition to the scaling issues for this architecture related to searching, there is also a problem with response time for assembling a patient record. When a given patient record is requested, the locations where the patient has available records are found using the central index. Then, a **query-response cycle** is required for each location where patient records are available. Following completion of the query-response cycles, all the information obtained must be integrated into a comprehensive record and made available to the requestor. While the query-response cycles can all be done in parallel, the final integration of results must wait for the slowest response. As the number of connected systems increases, so does the probability of a slow (or absent) response from one of them when queried for patient records. In addition, more systems mean more processing time to integrate multiple sources of information into one coherent record. Thus, the response time will become slower as the number of connected systems increases.

The institution-centric architecture also introduces high levels of operational complexity.

Fig. 13.3 Example of a Network Operations Center (NOC) (Reproduced with permission from Evans Consoles Corporation)

Since the completeness of retrieval of a given patient's records is dependent on the availability of all the systems that contain information about that patient, ongoing real-time monitoring of all connected information sources is essential. This translates into a requirement for a 24×7 **network operations center** (**NOC**), that constantly monitors the operational status of every medical information system and is staffed with senior IT personnel who can immediately troubleshoot and correct any problems detected (Fig. 13.3). Even with modest system failure rates (e.g., 1/1000), a community with thousands of EHRs will typically have a handful of systems that are unresponsive to queries for patient records and require immediate expert attention to restore to full operation. The cost of this around-the-clock monitoring is very substantial, since a staff of at least five full-time network engineers is required to assure that at least one person is always available for every shift 7 days a week.

In addition to the cost of the NOC, every EHR system in an institution-centric model must always be able to respond to queries in real-time. In addition to the cost of assuring 24×7 operation of all these systems, which will be extremely problematic for physician offices, every system will need additional hardware, software, and telecommunications capabilities to simultaneously support such queries while also serving its local users. Clearly, the transaction volumes generated will be substantial, since each patient's records will be queried whenever they receive care at any location. Contrast this to a central repository model where the information from a care episode is transmitted once to the repository and no further queries to the source system are ever needed. This analysis has recently been confirmed by a simulation study of the institution-centric architecture demonstrating that both the transaction volume and probability of incomplete records (from missing data due to a malfunctioning network node) increase exponentially with the average number of sites where each patient's data is located (Lapsia et al. 2012).

13.5.2 Patient-Centric Architecture (Health Record Banking)

Health record banking is a patient-centric approach to developing community HII that both addresses the key requirements and can overcome the challenges that have stymied current efforts (Yasnoff 2006). A **health record bank** (**HRB**) is defined as "an independent organization that provides a secure electronic repository for storing and maintaining an individual's lifetime health and medical records from multiple sources and assures that the individual always

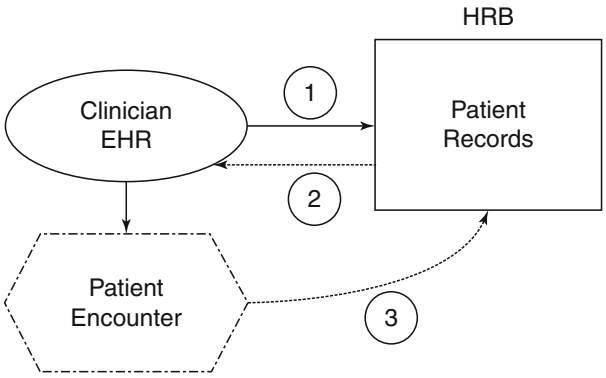

Fig. 13.4 Patient-centric HII architecture. *1*. The clinician EHR requests prior patient records from the HRB. *2*. The prior patient records are immediately sent to the clinician EHR. *3*. After the care episode, the new information is stored in the clinician EHR and sent to the HRB; any inconsistencies or incompatibilities with prior records in the HRB need to be resolved before that patient's records are requested again (but not in real time). (Note: this process is repeated whenever care is provided, resulting in the accumulation of each patients's records from all sources in the HRB) (© Health Record Banking Alliance, 2013. Used with permission)

has complete control over who accesses their information" (HRBA 2008).

Using a community HRB to provide patient information for medical care is straightforward (Fig. 13.4). Prior to seeking care (or at the time of care in an emergency), the patient gives permission for the caregiver to access his/her HRB account records (either all or part) through a secure Internet portal. The provider then accesses (and optionally, downloads) the records through a similar secure web site. When the care episode is completed, the caregiver then transmits any new information generated to the HRB to be added to the account-holder's lifetime health record. The updated record is then immediately available for subsequent care.

The health record banking concept has been evolving for nearly two decades since it was initially proposed (Szolovits et al. 1994). The term "health information bank" was introduced in 1997 in the U.K. (Dodd 1997), and was subsequently described as the "bank of health"(Ramsaroop and Ball 2000). A legal analysis of the implications of a "health record trust" was published in 2002 (Kostyack 2002), an Italian system known as the "health current account" was described in 2004 (Saccavini and Greco 2004), and the "health record bank" concept was described by Dyson in 2005 (Dyson 2005). In 2006, a Heritage Foundation policy paper endorsed health record banking (Haislmaier 2006), additional papers described HRBs in more detail (Ball and Gold 2006; Shabo 2006), the non-profit Health Record Banking Alliance was formed (HRBA 2006), the State of Washington endorsed the concept after a 16-month study (State of Washington 2006), and the non-profit Dossia consortium was formed by several large employers to implement and operate an HRB for their employees (Dossia 2006). In 2007, the Information Technology and Innovation Foundation recommended that the health record banking approach be used to build the U.S. HII (Castro 2007), while Gold and Ball described the "health record banking imperative" (Gold and Ball 2007). That same year, both Microsoft and Google introduced patient-controlled medical record repositories. In 2009, three pilot HRBs were funded by the State of Washington, another one was started in Rotterdam, Netherlands,[1] and the role of HRBs in protecting privacy was described (Kendall 2009). The HRB concept, although not always named as such, is now appearing with greater frequency in articles discussing the need for comprehensive EHRs (Steinbrook 2008; Mandl and Kohane 2008; Kidd 2008; Miller et al. 2009; Krist and Woolf 2011).

13.5.2.1 Patient Control Ensures Privacy and Stakeholder Cooperation

In an HRB, everything is done with *consumer consent*, with account-holders controlling their copy of all their records and deciding who gets to see any or all of it. This protects privacy (since each consumer sets their own customized privacy policy), promotes trust, and ensures stakeholder cooperation since all holders of medical information must provide it when requested by the patient (Kendall 2009). Of course, the operations of an HRB must be open and transparent with

[1] http://webwereld.nl/nieuws/54340/rotterdam-start-eigen-versie-elektronisch-pati--ntendossier.html. Posted January 14, 2009. (accessed 21Apr 2013).

independent auditing of privacy practices. World-class state-of-the-art computer security is needed to protect the HRB, which will be a natural target for hackers. However, this is no different from any other system design for HII, even if the information is not stored centrally, since by definition any such system must be capable of immediately assembling a complete patient record on request.

Natural concerns arise from the ability of the patient to suppress any or all of their HRB account information, which could lead to misdiagnosis and dangerous treatment. This capability could be abused by patients who, for example, may seek multiple prescriptions for controlled substances for the purpose of diversion for illegal sale. With respect to the possibility of medical errors resulting from incomplete information, the patient would be clearly and unmistakably warned about this when choosing not to disclose any specific information (e.g., "Failure to disclose any of your medical information may lead to serious medical problems, including your death"). The expectation is that few people will choose to do this, particularly after such a warning. However, as noted earlier, 13–17 % of patients already engage in this practice, leading many observers to conclude that the general public may not be comfortable with a system that provides easy access to their records unless they are in control of such access. This issue ultimately becomes one of public policy and may also be a subject of discussion between the doctor and the patient (i.e., the doctor will want to be assured by the patient that all information is being provided). Clearly, physicians should not be liable for the consequences of the patient's choice to withhold information.

With respect to patients who use their power to withhold information as a way to facilitate improper or illegal activity, there is clearly an overriding public policy concern. For example, in the case of controlled substances, it may be necessary to report to the physician (or, if legislatively mandated, to regulatory authorities) whenever a patient suppresses any information about controlled substance prescriptions. The information itself would still be under the patient's control, but the physician would be alerted with a notice such as "some controlled substance prescription information has been withheld at the patient's request." There may be other situations where such warnings are needed.

13.5.2.2 Assuring the Information Is in Electronic Form and Complies with Standards

HRBs can provide ongoing incentives for EHR adoption by clinicians. To ensure electronic information, all providers must have EHRs. As indicated earlier, since most of the economic benefits of office-based EHRs do not accrue to providers, high levels of outpatient EHR adoption will most likely require some kind of ongoing compensation or value for their costs. For physicians who already have EHR systems, a per-encounter or per-month payment system can be used. Those physicians who do not currently have EHRs could receive no-cost Internet-accessible EHR systems (at HRB expense) with the understanding that information from patient encounters will be automatically transferred to the HRB. "Meaningful Use" of those EHRs is assured and can be easily audited on an ongoing basis since the information from each patient encounter must be deposited in the HRB. It is even possible to link reimbursement for medical services to HRB deposits – i.e., providers would not be paid unless the medical record information generated from those services is transmitted to an HRB. This makes sense economically, as the value of medical services is greatly limited if the information about patients is not readily available for their ongoing care.

HRBs also serve to ensure compliance with data standards, both initially and on an ongoing basis. Clearly, any EHR provided through the HRB can, by definition, transmit information back to the HRB in a standard format (since the HRB only provides systems that can do so). For physicians who already have EHRs, HRB reimbursements for those systems naturally require standard transactions to be used to send encounter data to the HRB. Over time, higher levels of encoding of medical information can be promoted through the gradual introduction of more stringent standards requirements (with plenty of lead time to allow for system upgrades).

Compliance with such changes in standards can also be assured through the direct relationship to reimbursement.

13.5.2.3 Business Model

Health record banking has advantages on both the cost and revenue sides of the business model; the cost is lower and the revenue opportunities greater. Because of the lower operating costs and additional functionality for searching records, one can envision a variety of business models for HRBs that do not depend on public subsidies or attempt to capture any health care savings, but are solely funded through new value created for consumers and other stakeholders (HRBA 2012).

Due to the simplicity of HRB operations, the cost is substantially less than an equivalent institution-centric architecture. For an HRB, providing access at the point of care only involves a single retrieval from the bank's repository of records. In an institution-centric model, the records for a given patient are located at an arbitrary number of dispersed sites, and must be assembled in real-time and integrated into a comprehensive record before they can be used for patient care. Not only is this process of assembly complex, time-consuming, and prone to error, it necessitates, as noted above, the creation of a fully staffed 24×7 NOC to monitor the availability of all information sources as well as troubleshoot and correct those that are malfunctioning.

The estimated cost for the NOC in an institution-centric model is substantial. For example, given a population of 1,000,000, at least 1,000 systems would need monitoring (1 for every 1,000 patients). Assuming a reasonable failure rate for fully functional query connectivity to each system of once/year (representing a **mean time between failures** [**MTBF**] of over 8,700 h), there would be an average of 2.73 failures/day or 0.91 failures per 8-h shift that would need troubleshooting attention. A minimum staff for the NOC would be 1 person 24×7; given 21 shifts/week plus leeway for vacations and sick leave, this would require at least 5 full-time equivalent staff costing about $200,000 each including equipment, overhead and fringe benefits. Assuming an additional $500,000/year for hardware and software to operate the institution-centric system (over and above the data repository needed for an HRB) yields an annual cost of $1.5 million or $1.50/person/year. This would add nearly 20 % for the institution-centric model to the estimated $8/person/year needed to operate an HRB (Kaelber et al. 2008).

Beyond this, the additional costs imposed in the institution-centric model for each connected EHR for additional hardware, software, telecommunications capability, and additional operational expenses to maintain 24×7 system availability must also be included. Even if such costs were only a very modest $1,000/year/system (less than $100/month), this would result in an additional $1,000,000 or $1/person/year. Adding this to the $1.50/person/year for the NOC gives a total estimated cost of $2.50/person/year, resulting in over 30 % higher costs for the institution-centric model than a basic HRB. Added to this would be the costs and complexity of establishing and maintaining data sharing agreements among all the entities, which would be substantial.

On the revenue side, the inability of the institution-centric model to efficiently search the data impedes generation of potentially significant revenue from consumer applications and research. For example, generating medication refill reminders to consumers alone could potentially yield $20/year of revenue per consumer, paid by pharmaceutical firms as a completely ethical and appropriate mechanism to improve both compliance and their own bottom line. Even if only 20 % of consumers used this service, potential average revenue from this application alone would be $4/person/year, half the estimated HRB cost.

Another key source of revenue could be targeted advertising to consumers (based on the information in their accounts), which could generate an estimated $6/person/year or more. Consumers would also be allowed to opt-out of such advertising by paying the $6/year. To protect privacy, advertisers would not be allowed to identify anyone viewing their ads unless the consumer voluntarily provided contact information.

Revenue from searching the data (with consumer permission) could also be substantial. Finding eligible subjects for clinical trials is quite

Table 13.1 Comparison of the institution-centric and patient-centric approaches to Health Information Infrastructure

Issue	Institution-centric	Patient-centric (HRB)
Cooperation needed	Extensive; community-wide	Unifying; HIPAA mandates records on patient request
Organizational complexity	High; ongoing collaboration of multiple competing stakeholders necessary	Low; HRB is neutral and independent of all stakeholders
Privacy	Patient consent difficult to implement; many complex data sharing agreements needed	Simple; patients in control of all access to their own records; consent easy to implement
Startup funding	Substantial (due to high complexity)	Minimal
Business model	Complex; no clear approach has emerged	Flexible; many options possible funded by patients/payers/purchasers
Clinician EHR incentives	Not included	Easy to include
Clinician EHR processing burden	Extensive; incoming query each time current patients seen anywhere	Minimal; information deposited once in HRB; no incoming queries
Interoperability (data standards)	Compliance voluntary	Compliance can be assured with financial incentives
IT system design	Complex; requires queries to multiple entities, real-time reconciliation of inconsistencies, and NOC	Simple; no secondary queries or real-time reconciliation needed; NOC unnecessary
Completeness of patient records	Requires data source queries each time a patient's records are requested; all must respond for completeness	Comprehensive data available at all times for each patient

expensive, and could be greatly facilitated by sending electronic invitations directly to qualified patients identified through an HRB (to protect privacy, the identities of the recipients of the invitations could be hidden from the researchers). Also, anonymized reports from searches of HRB data would be very valuable to medical researchers, public health officials, and policymakers. Reasonable fees for such reports would therefore be another important revenue source. While it is difficult to estimate the magnitude of this revenue, it seems likely that it would be at least a few dollars per patient each year.

Finally, the low cost of HRBs allows them to subsidize outpatient EHRs. To cover fully the expense of office-based EHRs costs about $10/person/year. This is based on a cost of $5,000/year/physician for an internet-accessible EHR (a high estimate) allocated to 500 people (300 million U.S. population divided by 600,000 physicians needing EHRs). Given the strong revenue potential for HRBs, this additional $10/person/year expense could be included in operating costs over and above the expected $8/person/year anticipated as baseline expenditures. There are several key advantages if the HRB assumes these costs: (1) it promotes much higher levels of EHR adoption, thereby ensuring that more patient information is electronic; (2) it allows the HRB to ensure that EHRs submit data using standards (by subsidizing only compliant EHRs); (3) it provides a mechanism for ensuring updates to standards as they are needed; and (4) it creates a mutually beneficial relationship with clinicians that facilitates their cooperation as a marketing channel for HRB (by offering no-cost accounts to their patients). While the additional $10/person/year for EHRs is a substantial cost burden, revenue opportunities from value-added applications, consumer advertising, and research could more than cover the resultant total operating costs of $18/person/year without the need to quantify or capture any potential health care savings.

Table 13.1 summarizes the characteristics of the institution-centric approach to HII compared

to the patient-centric (health record bank) model. The patient-centric model is simpler and more straightforward, and deals directly with the issue of privacy by putting patients in control of their own information. Interoperability is much more easily accomplished in the patient-centric model since standards compliance can be reinforced with financial incentives, and reconciliation of inconsistencies between records need not be real-time. The patient centric approach is financially sustainable with a variety of business models, and can provide powerful incentives to clinicians to acquire EHRs. Finally, the patient-centric model avoids the substantial processing burden on clinician EHRs from queries each time any patient whose record is stored is seen anywhere.

13.6 HII Evaluation

The last element in the strategy for promoting a complex and lengthy project such as the HII is evaluation to both gauge progress and define a complete system. Evaluation measures should have several key features. First, they should be sufficiently sensitive so that their values change at a reasonable rate (a measure that only changes value after 5 years will not be particularly helpful). Second, the measures must be comprehensive enough to reflect activities that affect most of the stakeholders and activities needing change. This ensures that efforts in every area will be reflected in improved measures. Third, the measures must be meaningful to policymakers. Fourth, periodic determinations of the current values of the measures should be easy so that the measurement process does not detract from the actual work. Finally, the totality of the measures must reflect the desired end state so that when the goals for all the measures are attained, the project is complete.

A number of different types or dimensions of measures for HII progress are possible. Aggregate measures assess HII progress over the entire nation. Examples include the percentage of the population covered by an HII and the percentage of health care personnel who utilize EHRs. Another type of measure is based on the setting of care. Progress in implementation of EHR systems in the inpatient, outpatient, long-term care, home, and community environments could clearly be part of an HII measurement program. Yet another dimension is health care functions performed using information systems support, including, for example, registration systems, decision support, and CPOE. Finally, it is also important to assess progress with respect to the semantic encoding of EHRs. Clearly, there is a progression from the electronic exchange of images of documents, where the content is only readable by the end user viewing the image, to fully encoded EHRs where all the information is indexed and accessible in machine-readable form using standards.

Sadly, the evidence is now overwhelming that U.S. HIEs in their current form are, with rare exceptions, not succeeding. Labkoff and Yasnoff described four criteria for the quantitative evaluation of HII progress in communities: (1) completeness of information, (2) degree of usage, (3) types of usage, and (4) financial sustainability (Labkoff and Yasnoff 2007). Using these criteria, four of the most advanced community HII projects in the U.S. achieved scores of 60–78 % (on a 0–100 scale), indicating substantial additional work was required before the HII could be viewed as complete.

The 2010 PCAST report stated, "*HIEs have drawbacks that make them ill-suited as the basis for a national health information architecture*" (PCAST 2010). Among those drawbacks, PCAST cited administrative burdens (data sharing agreements to ensure stakeholder cooperation), financial sustainability, interoperability, and an architecture that cannot be scaled effectively. The most recent (Adler-Milstein et al. 2011) of a series of surveys of HIEs (Adler-Milstein et al. 2008, 2009) found only 13 HIEs in the U.S. (covering 3 % of hospitals and 0.9 % of physician practices) capable of meeting Stage 1 Meaningful Use criteria, and even those metrics by no means ensure the availability of comprehensive electronic patient information when and where needed. Of those, only six were reported to be financially viable. More importantly, *none* of the HIEs surveyed had the capabilities of a comprehensive system as specified by an expert panel.

Overall, the current approaches to building HII consistently fail to meet one or more of the requirements described above: privacy, stakeholder cooperation, ensuring fully electronic information, financial sustainability, and independent governance. While these problems are highly interdependent, it is useful to consider them in the context of the decisions that communities have made about HII architecture, privacy, and business model that, while appearing attractive to stakeholders in the short term, have so far been largely unsuccessful. Exploration and large-scale testing of alternative approaches that directly address the requirements, such as health record banking, seem both necessary and increasingly urgent.

13.7 Conclusion

While progress has been made and efforts are continuing, successful development and operation of comprehensive HII systems remains a largely unsolved problem. The extensive focus on building HII systems has greatly improved our understanding of the requirements, barriers, and challenges, as well as potential solutions. Despite the daunting obstacles, the benefits of HII are sufficiently urgent and compelling to ensure major ongoing work in this domain. Through these activities, the HII path to comprehensive electronic patient records when and where needed is becoming clearer, and substantial advances are likely in the next few years.

Suggested Readings

Aanestad, M., & Jensen, T.B. (2011). Building nationwide information infrastructures in healthcare through modular implementation strategies. *Journal of Strategic Information Systems, 20*(2), 161–176. An interesting study comparing two large-scale HII implementations, one of which failed, suggesting that both a gradual transition of the installed base and a modular approach are needed for success.

Adler-Milstein, J., Bates, D.W., & Jha, A.K. (2011). A survey of health information exchange organizations in the United States: Implications for meaningful use. *Annals of Internal Medicine, 154*, 666–671. The recent comprehensive survey of 179 HIEs that found that none of them had comprehensive capabilities and concluded that the current development path was unlikely to succeed.

Castro D. (2007) *Improving health care*: *Why a dose of IT may be just what the doctor ordered*. Information Technology and Innovation Foundation. Available at http://www.itif.org/publications/improving-health-care-why-dose-it-may-be-just-what-doctor-ordered. Accessed 17 Dec 2012. This is the first independent report that endorsed patient-centric architecture (HRBs) as an effective approach to HII. It describes clearly the problems and challenges of HIEs.

Krist, A.H., & Woolf, S.H. (2011). A vision for patient-centered health information systems. *JAMA: The Journal of the American Medical Association, 305*(3), 300–301. A vision of how fully functional patient-centric electronic medical record systems could be the basis for an effective HII.

Miller, R.H., & Miller, B.S. (2007). The Santa Barbara County Care Data Exchange: What happened? *Health Affairs, 26*(5), 568w–580w. This paper describes the history of one of the earliest HIEs, including details about the factors leading to its failure.

National Committee on Vital and Health Statistics. (2001). *Information for health*: *A strategy for building the National Health Information Infrastructure*. *Report and recommendations from the National Committee on Vital and Health Statistics*. Available at http://www.ncvhs.hhs.gov/nhiilayo.pdf. Accessed 17 Dec 2012. This seminal work was the first to call for a national HII, coining the term. It comprehensively describes the need for HII, the problems it would solve, and the necessity for government investment to incentivize its development.

Steinbrook, R. (2008). Personally controlled online health data—The next big thing in medical care? *The New England Journal of Medicine, 358*(16), 1653–1656. A physician's perspective on the need for patients to control their own electronic health data.

Yasnoff, W.A., Humphreys, B.L., Overhage, J.M., Detmer, D.E., Brennan, P.F., Morris, R.W., Middleton, B., Bates, D.W., & Fanning, J.P. (2004). A consensus action agenda for achieving the national health information infrastructure. *Journal of the American Medical Informatics Association, 11*(4), 332–338. This paper describes the results of the first national consensus conference on HII held in Washington, DC, in 2003. This was the meeting that led to the creation of ONC in 2004.

Questions for Discussion

1. Make the case for and against investing $billions in the HII. How successful have the HITECH Meaningful Use incentives been in promoting HII development? What could be done to make them more effective?
2. What organizational options would you consider if you were beginning the development of HII? What are the pros and cons of each? How would you proceed with making a decision about which one to use?
3. Estimate the required bandwidth and transaction rate for central (HRB) vs. institution-centric HII architecture.
4. Consider the policy implications of universal availability of comprehensive electronic patient records. What are the risks and how could they be mitigated?
5. Given the architectural and other advantages of HRBs, why have most communities adopted institution-centric architectures up to now? What are some steps that might be helpful in encouraging communities to evaluate alternative architectures such as HRBs?
6. Show specifically the potential locations where patient consent functionality could be added to the institution-centric and patient-centric HII architectures in Figs. 13.2 and 13.4 and describe the granularity of consent that would be possible at each proposed location. After eliminating any redundant functionality, compare and contrast the consent implementation issues for the two alternative architectures, describing the advantages and disadvantages of each. Which architecture more efficiently addresses the issue of patient consent? Why?

Management of Information in Health Care Organizations

14

Lynn Harold Vogel

After reading this chapter, you should know the answers to these questions:

- What are the primary information requirements of health care organizations (HCOs)?
- What are the clinical, financial, and administrative functions provided by health care information systems (HCISs), and what are the potential benefits of implementing such systems?
- How have changes in health care delivery models changed the scope and requirements of HCISs over time?
- How do differences among business strategies and organizational structures influence information systems choices?
- What are the major challenges to implementing and managing HCISs?
- How are ongoing health care reforms, technological advances, and changing social norms likely to affect HCIS requirements in the future?

14.1 Overview

Health care organizations (HCOs), like many other business entities, are information-intensive enterprises. Health care personnel require sufficient data and information management tools to make appropriate decisions. At the same time, they need to care for patients and manage and run the enterprise; they also need to document and communicate plans and activities, and to meet the requirements of numerous regulatory and accrediting organizations. Clinicians assess patient status, plan patient care, administer appropriate treatments, and educate patients and families regarding clinical management of various conditions. They are also concerned about evaluating the clinical outcomes, quality, and increasingly, the cost of health services provided. Administrators determine appropriate staffing levels, manage inventories of drugs and supplies, and negotiate payment contracts for services. Governing boards make decisions about whether to invest in new business lines, how to partner with other organizations, and how to eliminate underutilized services. Collectively, health care professionals comprise a heterogeneous group with diverse objectives and information requirements.

The purpose of **health care information systems** (HCISs) is to support the access and management of the information that health professionals need in order to perform their jobs effectively and efficiently. HCISs facilitate communication, integrate information, and coordinate action among multiple health care professionals.

L.H. Vogel, PhD
LH Vogel Consulting, LLC,
371 Beveridge Road, Ridgewood, NJ 07450, USA
e-mail: lynn@lhvogelconsulting.com

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In addition, they assist in the organization and storage of data, and they support certain record-keeping and reporting functions. Many of the clinical information functions of an HCIS were detailed in our discussion of the computer-based patient record (CPR) in Chap. 12; systems to support nurses and other care providers are discussed in Chap. 15. Furthermore, HCISs are key elements that interface with the health information infrastructure (HII), as discussed in Chap. 13. An HCIS also supports the financial and administrative functions of a health organization and associated operating units, including the operations of ancillary and other clinical-support departments. The evolving complexities of HCOs place great demands on an HCIS. Many HCOs are broadening their scope of activities to cover the care continuum, partially in response to **Accountable Care Organization** (**ACO**) initiatives from the federal government. HCISs must organize, manage, and integrate large amounts of clinical and financial data collected by diverse users in a variety of organizational settings (from physicians' offices to hospitals to health care systems) and must provide health care workers (and, increasingly, patients) with timely access to complete, accurate, and up-to-date information presented in a useful format.

14.1.1 Evolution from Automation of Specific Functions to Health care System Information Systems

Over time, changes in the health care economic and regulatory environments have radically transformed the structure, strategic goals, and operational processes of health care organizations through a gradual shifting of financial risk from third party payers (e.g., traditional insurance companies such as Blue Cross and Blue Shield, Medicare and Medicaid programs that emerged in the 1960s and 1970s, and subsequently managed care companies that became quite prominent in the 1980s) to the providers themselves. This shifting of risk initially brought about a consolidation of health care providers into **integrated delivery networks** (IDNs) in the 1990s. Subsequently, there was a retreat from the most restrictive models of managed care toward greater consumer choice, a slowing of mergers and acquisitions activities, several high profile IDN failures (Shortell et al. 2000, Weil 2001, Kastor 2001), and major new regulatory requirements aimed at improved efficiency and greater patient privacy and safety. Most recently, the pendulum has swung back as IDNs acquire both physician practices and hospitals while shifting their focus to becoming identified as an **ACO**. All these changes have tremendous implications for HCISs.

The evolution of HCISs has paralleled—and in many ways responded to—the organizational evolution of the health care industry itself. The earliest HCISs were largely focused on the automation of specific functions within hospitals including, initially, patient registration and billing. The justification for these systems was relatively straightforward since large mainframe computers were easily capable of performing the clerical tasks associated with tracking patients and sending out bills. In the 1960s and 1970s, seeing the benefits coming from more highly automated financial systems, hospital departments began to focus on installing computer systems to support ancillary activities such as those found in radiology, the pharmacy, and the laboratories. Hardware vendors such as the Digital Equipment Corporation (DEC) responded with smaller computing platforms known as **minicomputers**, which enabled individual departments to remain quite separate not only in function but in terms of computer hardware, operating systems, and even programming languages—even though collectively they were now known as **hospital information systems** (HISs). The lack of connectivity among these various systems created significant obstacles to keeping track of where patients were located in a hospital, and more importantly, what kind of care was being provided and the clinical results of that care. It was not uncommon for caregivers to have to log on to several different computer systems just to learn the status of specific clinical results from different laboratories or departments. By the

late 1980s, **clinical information system** (CIS) components of HISs offered clinically oriented capabilities, such as order writing and results communications. During the same period, **ambulatory medical record systems** (AMRSs) and **practice management systems** (PMSs) were being developed to support large outpatient clinics and physician offices, respectively. These systems performed functions analogous to those of hospital systems, but were generally less complex, reflecting the lower volume and complexity of patient care delivered in outpatient settings. Increasingly, these various systems were implemented within organizational boundaries, but with little or no integration between hospital and ambulatory settings.

The development of so many different, functionally specific information systems is one of the unique attributes of HCOs and one of the drivers of the complexity of HCOs. These systems were often developed in isolation from one another as vendors focused on developing as much highly specialized functionality as possible—in effect, striving for a "**best of breed**" designation in the marketplace for their particular type of system. The isolation of these systems, even within a single organizational structure, was overcome in part by the development of interfaces between the various systems. Initially these interfaces focused on delivering patient demographic information from registration systems to the ancillary systems and data on specific clinical events (e.g., laboratory tests, radiology exams, medications ordered) from the ancillary systems to the billing system. However, as more information systems were added to the HCIS environment, the challenge of moving data from one system to another became overwhelming. In response, two unique developments occurred: (1) the **interface engine**; and (2) **Health Level Seven** (HL7), a standard for the content of the data messages that were being sent from one information system to another as discussed in Chap. 7.

The challenge of sharing data among many different information systems that emerged in the 1980s and 1990s was daunting. As we noted earlier, the various components of the HCISs were in most cases developed by different vendors, using different hardware (e.g., DEC, IBM), operating systems (e.g., PICK, Altos, DOS, VMS, MUMPS on minicomputers, and IBM's 360 OS on mainframes) and programming languages (e.g., BASIC, PL1, COBOL, MUMPS and even assembler). Sharing data among two different systems typically required a two-way interface—one to send data from System A to System B, the other to send data or acknowledge receipt from B back to A. Adding a third system didn't require simply one additional interface because the new system would in many cases have to be interfaced to both of the original systems, resulting in the possibility of six interfaces. Introducing a fourth system into the HCIS environment increased the complexity further, since it often meant the need for two-way interfaces to *each* of the original three systems, for a total of twelve (Fig. 14.1). With the prospect of interfaces increasing exponentially as new systems were added (represented by the formula, $I=n\ (n-1)$ where I represents the number of interfaces

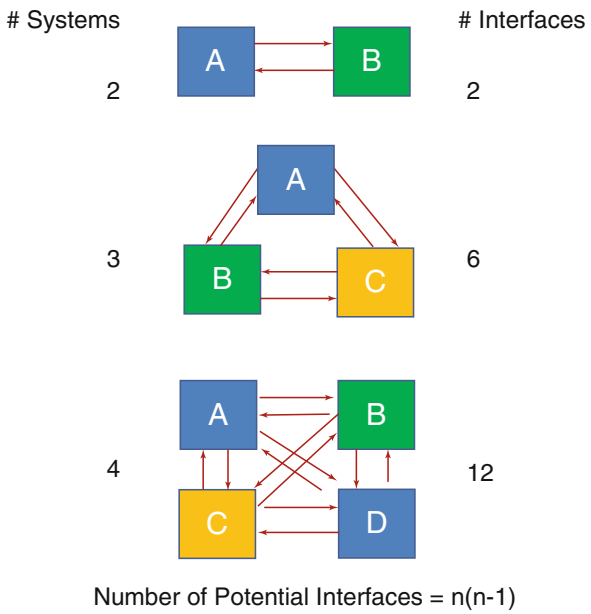

Fig. 14.1 The challenge of moving data from one system to another becomes complicated with the addition of each new system. Considering that even small size hospitals may have several hundred applications, interfacing is a major challenge. While in reality not all systems need to have two-way interfaces to every other system, this figure illustrates the challenges that even small numbers of systems bring

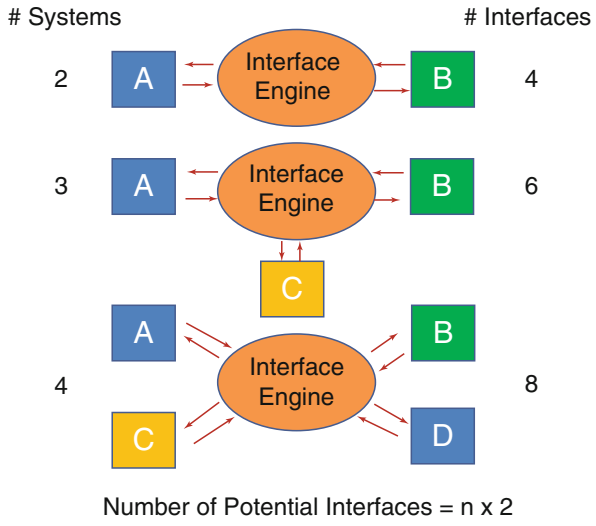

Fig. 14.2 The introduction of the Interface Engine (*IE*) made system interfaces much more manageable, particularly so with the implementation of HL7 data messaging standards. With an IE, each additional system only added two additional interfaces to the mix, one to send data and one to acknowledge receipt of the data

needed and *n* represents the number of systems), it was clear that a new solution was needed to address the complexity and cost of interfacing. In response, an industry niche was born in the late 1980s which focused on creating a software application designed specifically to manage the interfacing challenges among disparate systems in the HCIS environment. Instead of each system having to interface to every other system independently, the interface engine served as the central connecting point for all interfaces (Fig. 14.2). Each system had only to connect to the interface engine; the engine would then manage the sending of data to and from any other system that needed it. The interface engine concept, which originated in health care, has given rise to a whole series of strategies for managing multiple systems. Many of the vendors who got their start in health care interfacing subsequently found new markets in financial services as well as other industries.

The creation of HL7 (see Chap. 7) was yet another response to the challenge of moving data among disparate health care systems. HL7 is a health care-based initiative, also started in the late 1980s, to develop standards for the sharing of data among the many individual systems that comprise an HCIS. The basic idea was to use messaging standards so that data could be sent back and forth using standard formats within the HCIS environment. Most of the departmental systems that were introduced at this time were the products of companies focused on specific niche markets, including laboratories, pharmacies and radiology departments. Consequently there was strong support for both the interface engine and the HL7 efforts as mechanisms to permit smaller vendors to compete successfully in the marketplace. In recent years, many of these pioneering vendors have been purchased and their products included as components of larger product families.

The decade of the 1990s was marked by a large number of mergers and affiliations among previously independent and often competing HCOs designed to drive excess capacity from the system (e.g., an oversupply of hospital beds) and to secure market share. Hospitals and medical centers began to build satellite ambulatory-care clinics and to reach out to community physician practices in an attempt to secure patient referrals to their specialty services and to fill their increasingly vacant inpatient beds. Later, facing competition with **vertically integrated** for-profit health care chains and with other integrating organizations, hospitals started at first affiliating and then more tightly integrating into regional aggregates of health care service providers—the Integrated Delivery Networks (IDNs) mentioned earlier (See Fig. 14.3).

By 2000, IDNs were prominent in almost every health care market in the United States and in several cases, spanned large geographic regions and multiple states. Each IDN typically consisted of multiple acute-care facilities, satellite ambulatory health centers, and owned or managed physicians' practice groups. In addition, larger IDNs might have skilled nursing homes, hospices, home-care agencies, and for-profit sub-corporations to deliver support services back to the health care providers, including regional laboratories, separate organizations for purchasing and distributing drugs and medical supplies, and remote billing services. A major goal of such IDNs was cost reduction (both internally and from suppliers), as well as to retain or

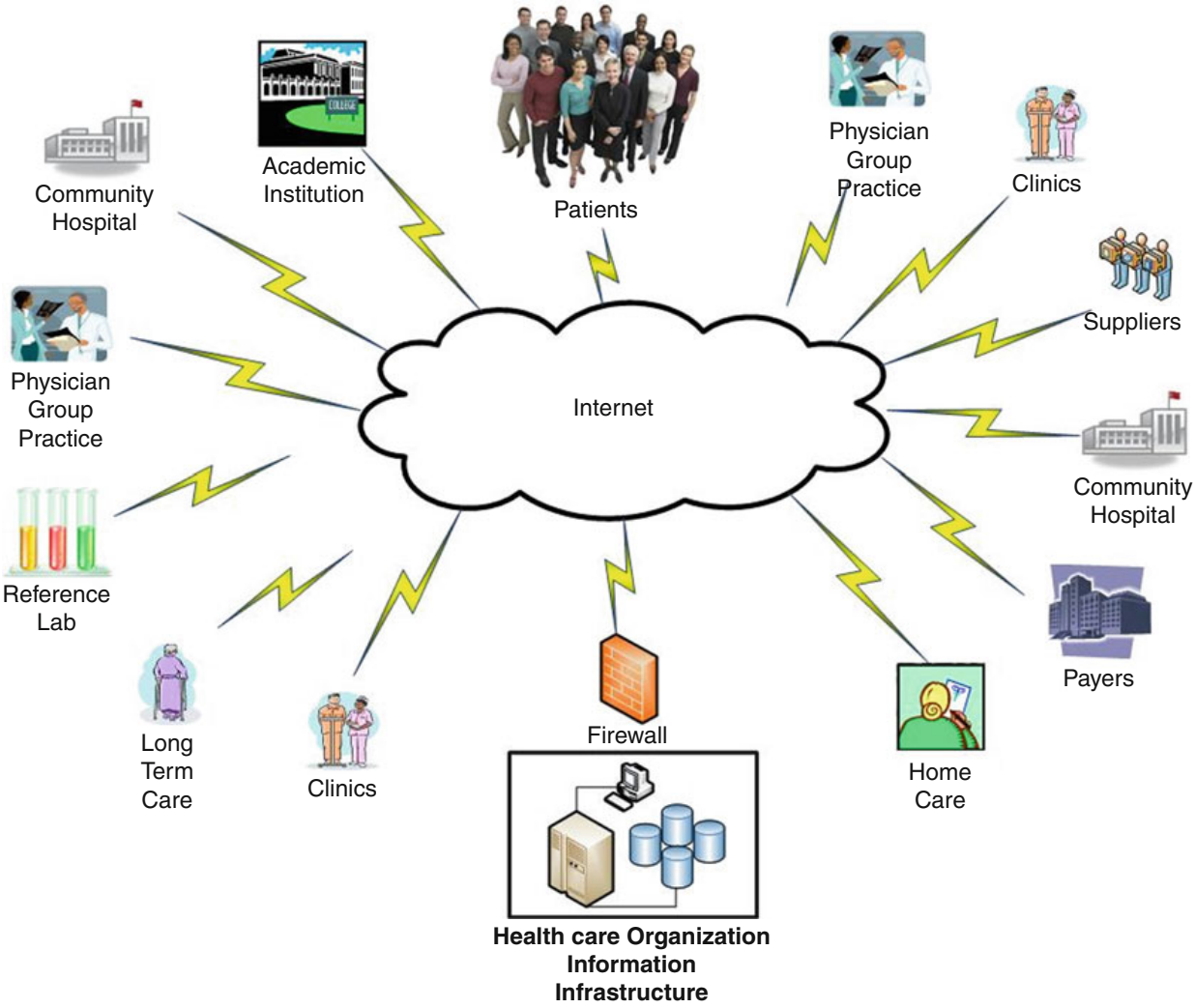

Fig. 14.3 Major organizational components of an integrated delivery network (IDN). A typical IDN might include several components of the same type (e.g., clinics, community hospitals. Physician group practices, etc.). Components within the same geographic area may have direct data connections, but increasingly the Internet is the preferred way to connect organizational components

increase revenues by improving their negotiating strength with third party payers. Because they controlled a significant regional market share and were positioned to provide and manage comprehensive health services, IDNs expected to negotiate favorable purchasing contracts with suppliers and competitive service contracts with payers or directly with large employers. Some IDNs went further and affiliated with a regional **health maintenance organization** (**HMO**) or developed their own health-plan organizations to act as their own insurance carriers. The largest IDNs had annual revenues approaching several billions of dollars, were contracting with thousands of physicians and nurses, and managed contracts to provide comprehensive care for more than one million patients.

One of the major expectations was that IDNs could reduce costs by leveraging economies of scale; for example, by consolidating administrative and financial functions and combining clinical services. Such IDNs were challenged to coordinate patient care and manage business operations throughout an extensive network of community and regional resources. As a result, HCISs were developed to share information and coordinate activities not only within, but among multiple hospitals, ambulatory care sites, physicians' practice groups, and other affiliated organizations.

Although IDNs are still a prominent feature in many health care markets, there had been a decrease in the rate of market consolidation and some highly visible IDN failures. While the most successful of IDNs have achieved a measure of structural and operational integration, gains from the integration of clinical activities and from the consolidation of information systems have been much more difficult. Many IDNs scaled back their original goals for integrating clinical activities and actually began to shed home care services, physician practices, health plans and managed care entities, although as noted earlier in this chapter, we are now seeing a return to consolidation, mergers and acquisitions as reimbursement constraints and federal ACO initiatives strive to improve both the efficiency and effectiveness of HCOs. It appears that the expertise gained from managing an inpatient-driven organization producing a relatively large amount of revenue from a relatively small set of events (e.g., a hospital) did not translate easily to the successful management of other organizational activities that in many cases required many more events to produce a similar level of revenue (e.g., from outpatient clinics). In some cases, it was even a challenge to translate management processes from inpatient operations to outpatient clinics, or one hospital to another. Attempts to apply hospital management principles to ambulatory clinics have been challenged because hospitals generate a relatively small number of patient bills with high dollar amounts whereas ambulatory clinics do just the opposite—generate a relatively large number of patient bills, each with a relatively small dollar amount. To date, it is fair to say that few IDNs have gained the degree of cost savings and efficiencies they had originally projected. The immense up-front costs of implementing (or integrating) the required HCISs in particular have contributed to this limited success. Regardless of organizational structure, all health care organizations are striving toward greater information access and integration, including improved information linkages with physicians and patients. The "typical" IDN is a melding of diverse organizations, and the associated information systems infrastructure is still far from integrated; rather, it remains in many cases an amalgam of heterogeneous systems, processes, and data stores.

14.1.2 Information Requirements

The most important function of any HCIS is to present data to decision makers so that they can improve the quality and timeliness of the decisions they need to make. From a clinical perspective, the most important function of an HCIS is to present patient-specific data to care givers so that they can easily interpret the data for diagnostic and treatment planning purposes, and support the necessary communication among the many health care workers who cooperate in providing health services to patients. From an administrative perspective, the most pressing information needs are those related to the daily operation and management of the organization—bills must be generated accurately and rapidly, employees and vendors must be paid, supplies must be ordered, and so on. In addition, administrators need information to make short-term and long-term planning decisions.

Since clinical system information requirements are discussed in Chaps. 12, 13, 15, and 22, we focus here on operational information needs, and specifically on four broad categories: daily operations, planning, communication, and documentation and reporting.

- *Operational requirements*. Health care workers—both care givers and administrators—require detailed and up-to-date factual information to perform the daily tasks that keep a hospital, clinic, or physician practice running—the bread-and-butter tasks of the institution. Here are examples of queries for operational information: Where is patient John Smith? What drugs is he receiving? What tests are scheduled for Mr. Smith after his discharge? Who will pay his bill? Is the staffing skill mix sufficient to handle the current volume and special needs of patients in Care Center 3 West? What are the names and telephone numbers of patients who have appointments for tomorrow and need to be

called for a reminder? What authorization is needed to perform an ultrasound procedure on Jane Blue under the terms of her health insurance coverage? HCISs can support these operational requirements for information by organizing data for prompt and easy access. Because the HCO may have developed product-line specialization within a particular facility (e.g., a diagnostic imaging center or women's health center), however, answering even a simple request may require accessing information stored in different systems at several different facilities.

- *Planning requirements*. Health professionals also require information to make short-term and long-term decisions about patient care and organizational management. The importance of appropriate clinical decision-making is obvious—we devote all of Chaps. 3 and 22 to explaining methods to help clinicians select diagnostic tests, interpret test results, and choose treatments for their patients. The decisions made by administrators and managers are no less important in their choices concerning the acquisition and use of health care resources. In fact, clinicians and administrators alike must choose wisely in their use of resources to provide high-quality care and excellent service at a competitive price. HCISs should help health care personnel to answer queries such as these: What are the organization's clinical guidelines for managing the care of patients with this condition? Have similar patients experienced better clinical outcomes with medical treatment or with surgical intervention? What are the financial and medical implications of closing the maternity service? If we added six care managers to the outpatient-clinic staff, can we improve patient outcomes and reduce emergency admissions? Will the proposed contract to provide health services to Medicaid patients be profitable given the current cost structure and current utilization patterns? Often, the data necessary for planning are generated by many sources. HCISs can help planners by aggregating, analyzing, and summarizing the information relevant to decision-making.
- *Communication requirements*. Communication and coordination of patient care and operations across multiple personnel, multiple business units, and far-flung geography is not possible without investment in an underlying technology infrastructure. For example, the routing of paper medical records, a cumbersome process even within a single hospital, is an impossibility for a regional network of providers trying to act in coordination. Similarly, it is neither timely nor cost effective to copy and distribute hard copy documents to all participants in a regionally distributed organization. An HCO's technology infrastructure can enable information exchange via web-based access to shared databases and documents, electronic mail, standard document-management systems, and on-line calendaring systems, as well as providing and controlling access for authorized users at the place and time that information is required.
- *Documentation and reporting requirements*. The need to maintain records for future reference or analysis and reporting makes up the fourth category of informational requirements. Some requirements are internally imposed. For example, a complete record of each patient's health status and treatment history is necessary to ensure continuity of care across multiple providers and over time. External requirements create a large demand for data collection and record keeping in HCOs (as with mandated reporting of vaccination records to public health agencies). As discussed in Chap. 12, the medical record is a legal document. If necessary, the courts can refer to the record to determine whether a patient received proper care. Insurance companies require itemized billing statements, and medical records substantiate the clinical justification of services provided and the charges submitted to them. The **Joint Commission** (**JC**), which certifies the qualifications and performance of many health care organizations, has specific requirements concerning the content and quality of medical records, as well as requirements for organization-wide information-management processes. Furthermore, to qualify for participation in the

Medicare and Medicaid programs, the JC requires that hospitals follow standardized procedures for auditing the medical staff and monitoring the quality of patient care, and they must be able to show that they meet the safety requirements for infectious disease management, buildings, and equipment. Employer and consumer groups are also joining the list of external monitors.

14.1.3 Integration Requirements

If an HCO is to manage patient care effectively, project a focused market identity, and control its operating costs, it must perform in a unified and consistent manner. For these reasons, information technologies to support data and process integration are recognized as critical to an HCO's operations. From an organizational perspective, information should be available when and where it is needed; users must have an integrated view, regardless of system or geographic boundaries; data must have a consistent interpretation; and adequate security must be in place to ensure access only by authorized personnel and only for appropriate uses. Unfortunately, these criteria are much easier to describe than to meet.

14.1.3.1 Data Integration

In hospitals, clinical and administrative personnel have traditionally had distinct areas of responsibility and performed many of their functions separately. Thus, it is not surprising that administrative and clinical data have often been managed separately—administrative data in business offices and clinical data in medical-records departments. When computers were first introduced, the hospital's information processing was often performed on separate computers with separate databases, thus minimizing conflicts about priorities in services and investment. As we have seen earlier in this chapter, information systems to support hospital functions and ambulatory care historically have, due to organizational boundaries, developed independently. Many hospitals, for example, have rich databases for inpatient data but maintain less information for outpatients—often including only billing data such as diagnosis and procedure codes and charges for services provided. Even today, relatively few clinical data are available in electronic format for most ambulatory-care clinics and physician offices in the United States, although this disparity is beginning to diminish as hospitals and physician practices continue a long term trend toward greater integration and increasing investments in HCISs. As **fee-for-service** reimbursement models continue to be challenged for their focus on activity-driven care, alternatives such as Accountable Care Organizations (ACOs), **bundled payments** for services, and **pay for performance** proposals will stimulate efforts toward greater data integration.

The historical lack of integration of data from diverse sources creates a host of problems. If clinical and administrative data are stored on separate systems, then data needed by both must either be entered separately into each system, be copied from one system to another, or data from both sources transferred to yet another location in order to be analyzed. In addition to the expense of redundant data entry and data maintenance incurred by these approaches (see also the related discussion for the health information infrastructure in Chap. 13), the consistency of information tends to be poor because data may be updated in one place and not in the other, or information may be copied incorrectly from one place to another. In the extreme example, the same data may be represented differently in different settings. As we noted earlier within the hospital setting, many of these issues have been addressed through the development of automated interfaces to transfer demographic data, orders, results, and charges between clinical systems and billing systems. Even with an interface engine managing data among disparate systems, however, an organization still must solve the thorny issues of synchronization of data and comparability of similar data types.

With the development of IDNs and other complex HCOs, the sharing of data elements among operating units becomes more critical and more problematic. Data integration issues are further

compounded in IDNs by the acquisition of previously independent organizations that have clinical and administrative information systems incompatible with those of the rest of the IDN. It is still not unusual to encounter minimal automated information exchange among organizations even within an IDN. Patients register and reregister at the physician's office, diagnostic imaging center, ambulatory surgery facility, and acute-care hospital—and sometimes face multiple registrations even within a single facility. Each facility may continue to keep its own clinical records, and shadow files may be established at multiple locations with copies of critical information such as operative reports and hospital discharge summaries. Inconsistencies in these multiple electronic and manual databases can result in inappropriate patient management and inappropriate resource allocation. For example, medications that are first given to a patient while she is a hospital inpatient may inadvertently be discontinued when she is transported to a rehabilitation hospital or nursing home. Also, information about a patient's known allergies and medication history may be unavailable to physicians treating an unconscious patient in an emergency department.

The objectives of coordinated, high-quality, and cost-effective health care cannot be completely satisfied if an organization's multiple computer systems operate in isolation. Unfortunately, free-standing systems within HCOs are still common, although HCOs and IDNs are increasingly investing in the implementation of new more consistent systems across all of their facilities or in integrating existing systems to allow data sharing. The capital investment required to pursue a strategy of system-wide data integration can be significant, and with ongoing challenges to reimbursement rates for both hospitals and physicians, the funding to pursue this strategy is often limited either due to competing investment requirements (e.g., acquiring or maintaining buildings and equipment) or the continued downward trend in reimbursement for services. In Sect. 14.4, we discuss architectural components and strategies for data integration.

14.1.3.2 Process Integration

To be truly effective, information systems must mesh smoothly with the people who use them and with the specific operational workflows of the organization. But **process integration** poses a significant challenge for HCOs and for the HCIS's as well. Today's health care-delivery models represent a radical departure from historical models of care delivery. Changes in reimbursement and documentation requirements may lead, for example, to changes in the responsibilities and work patterns of physicians, nurses, and other care providers; the development of entirely new job categories (such as care managers who coordinate a patient's care across facilities or between encounters); and the more active participation of patients in their own personal health management (Table 14.1). Process integration is further complicated in that component entities typically have evolved different operational policies and procedures, which can reflect different historical and leadership experiences from one office to another, or in the extreme example, from one floor to another within a single hospital. The most progressive HCOs are developing new enterprise-wide processes for providing easy and uniform access to health services, for deploying consistent clinical guidelines, and for coordinating and managing patient care across multiple care settings throughout the organization. Integrated information technologies are essential to supporting such enterprise-wide processes. Mechanisms for information management aimed at integrating operations across entities must address not only the migration from legacy systems but also the migration from legacy work processes to new, more consistent and more standardized policies and processes within and across entities.

The introduction of new information systems almost always changes the workplace. In fact research has shown that in most cases the real value from an investment in information systems comes only when underlying work processes are changed to take advantage of the new information technology (Vogel 2003; see Figs. 14.4 and 14.5). At times, these changes can be substantial. The implementation of a new system offers an

Table 14.1 The changing health care environment and its implications for an IDN's core competencies

Characteristics	Old care model	New care model
Goal of care	Manage sickness	Manage wellness
Center of delivery system	Hospital	Primary-care providers/ambulatory settings
Focus of care	Episodic acute and chronic care	Population health, primary and preventive care
Driver of care decisions	Specialists	Primary-care providers/patients
Metric of system success	Number of admissions	Number of enrollees
Performance optimization	Optimize individual provider performance	Optimize system-wide performance
Utilization controls	Externally controlled	Internally controlled
Quality measures	Defined as inputs to system	Defined as patient outcomes and satisfaction
Physician role	Autonomous and independent	Member of care team; user of system-wide guidelines of care
Patient role	Passive receiver of care	Active partner in care

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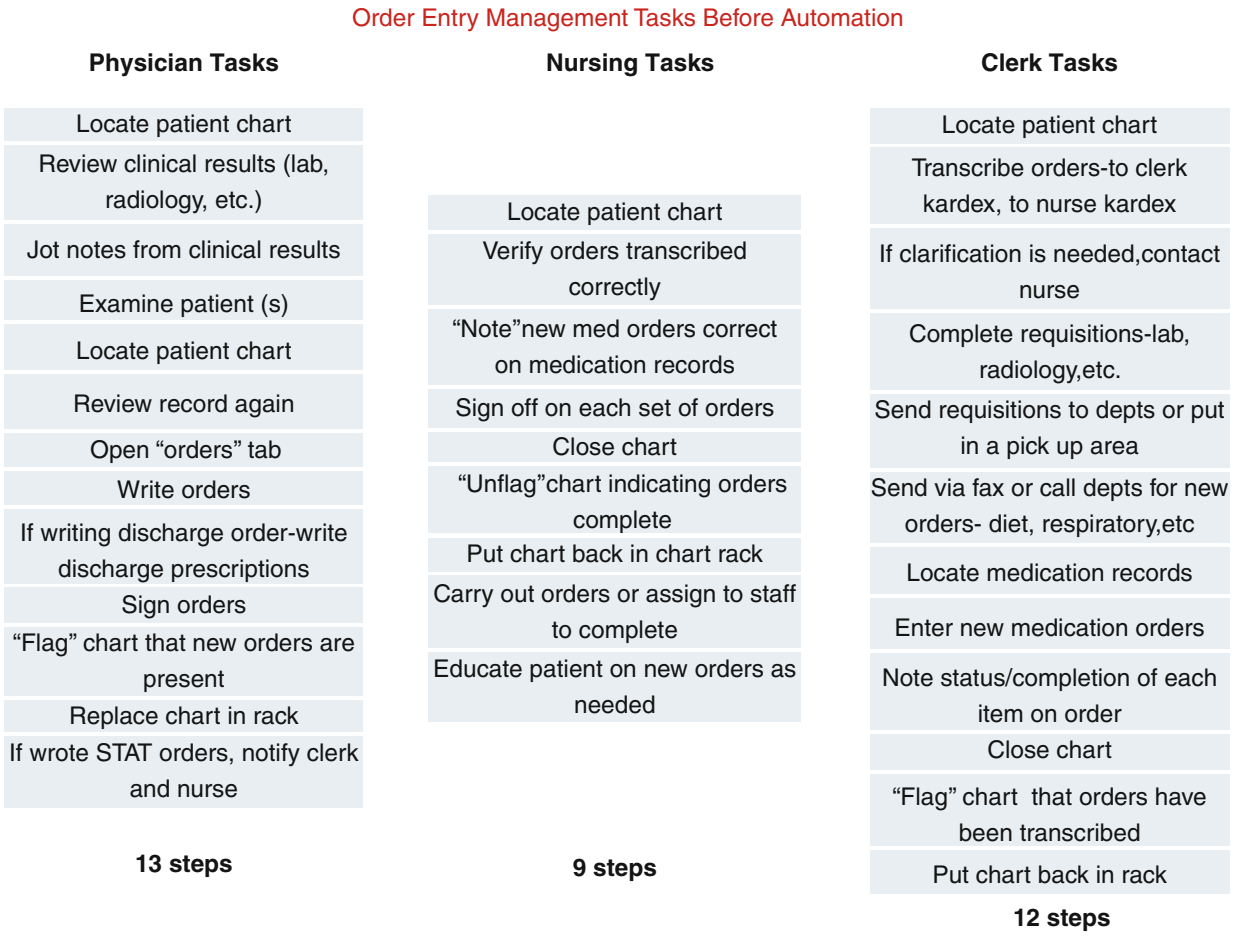

Fig. 14.4 The process of managing the manual creation of orders requesting services on behalf of patients in a hospital involves numerous tasks performed not only by the ordering physician, but by nursing and clerical staff

opportunity to rethink and redefine existing work processes to take advantage of the new information-management capabilities, thereby reducing costs, increasing productivity, or improving service levels. For example, providing electronic access to information that was previously accessible only on paper can shorten the overall time required to complete a multistep activity by enabling conversion of serial processes (completed by multiple workers using the

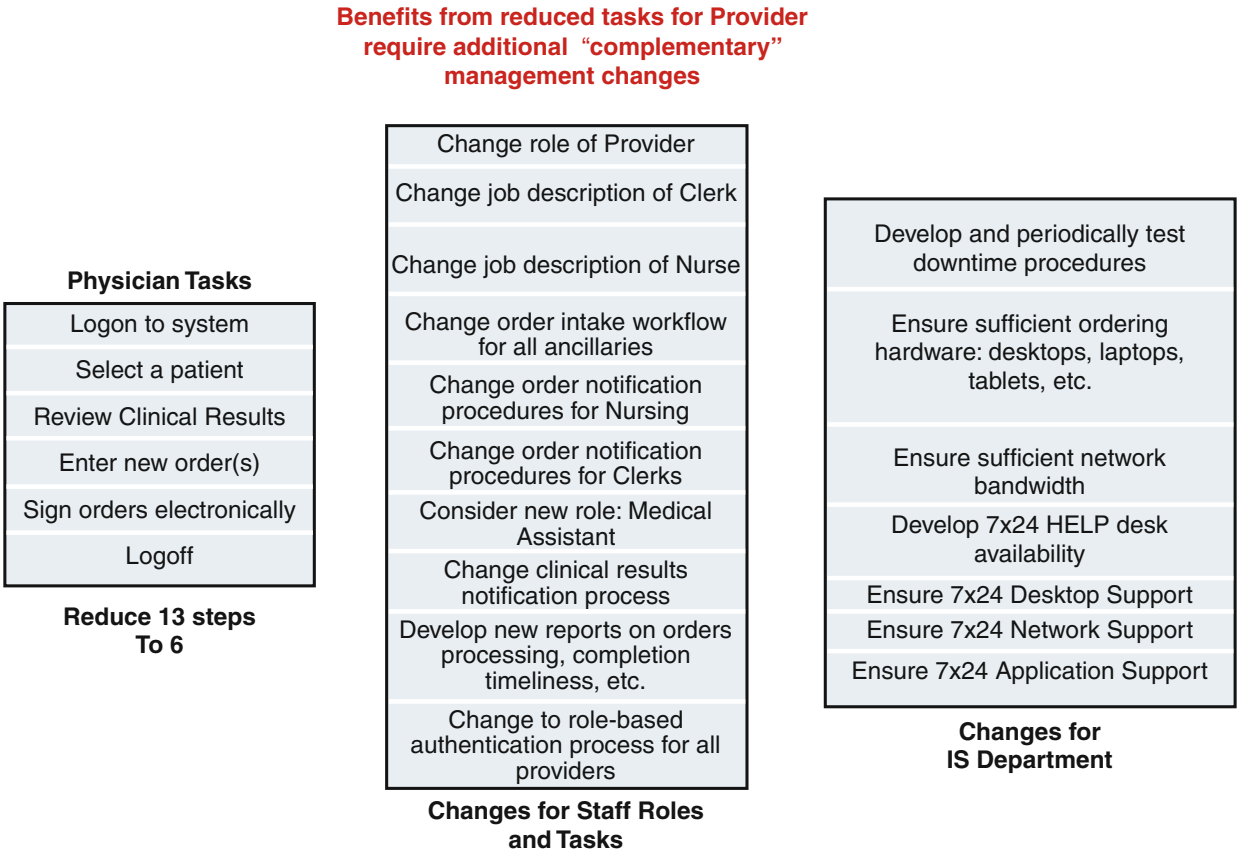

Fig. 14.5 The implementation of an electronic physician order entry system reduces the number of tasks that a physician needs to perform in order to enter an order, but such a system will only be successful if a number of other "complementary" changes are made to both the workflow of staff and the responsibilities of the IS Department

same record sequentially) to concurrent processes (completed by the workers accessing an electronic record simultaneously). More fundamental business transformation is also possible with new technologies; for example, direct entry of medication orders by physicians, linked with a decision-support system, allows immediate checking for proper dosing and potential drug interactions, and the ability to recommend less expensive drug substitutes.

Few health care organizations today have the time or resources to develop entirely new information systems and redesigned processes on their own; therefore, most opt to purchase commercial software products and to use consultants to assist them in the implementation of industry "best practices". Although these commercial systems allow some degree of custom tailoring, they also reflect an underlying model of work processes that may have evolved through development in other health care organizations with different underlying operational policies and procedures. In order to be successful, HCO's typically must adapt their own work processes to those embodied in the systems they are installing (For example, some commercial systems require care providers to discontinue and then reenter all orders when a patient is admitted to the hospital after being monitored in the emergency department). Furthermore, once the systems are installed and workflow has been adapted to them, they become part of the organization's culture—and any subsequent change to the new system may be arduous because of these workflow considerations. Decision-makers should take great care when selecting and configuring a new system to support and enhance desired work processes. Such organizational workflow adaptation represents a significant challenge to the HCO and its systems planners. Too often organizations are unable to realize the full potential return on

their information-technology investments when they attempt to change the system to accommodate historical work flows, even before the new system is installed. Such management practices can significantly reduce much of the potential gains from the HCO's IT investment.

To meet the continually evolving financial and quality documentation requirements of today's health care environment, HCOs must continually evolve as well—and the analogy between changing an HCO and turning an aircraft carrier seems apt. Although an HCO's business plans and information-systems strategies may be reasonable and necessary, changing ingrained organizational behavior can be much more complex than changing the underlying information systems. Technology capabilities often exceed an HCO's ability to use them effectively and efficiently. Successful process integration requires not only successful deployment of the technology but also sustained commitment of resources to use that technology well; dedicated leadership with the willingness to make difficult, sometimes unpopular decisions; education; and possibly new performance incentives to overcome cultural inertia and politics. Government incentives to stimulate HCOs toward the **meaningful use** of information technology, which emerged from the 2010 Health care Reform legislation (Chap. 27), are a recent example of attempts to bring process integration and data integration together.

14.1.4 Security and Confidentiality Requirements

The protection of health information from unwanted or inappropriate use is governed not only by the trust of patients in their health providers but also by law. In accordance with the **Health Insurance Portability and Accountability Act (HIPAA) of 1996** (Chap. 10), the Secretary of Health and Human Services recommended that "Congress enact national standards that provide fundamental privacy rights for patients and define responsibilities for those who serve them." This law and subsequent federal regulations now mandate standardized data transactions for sending data to payer organizations, the development and adherence to formal policies for securing and maintaining access to patient data, and under privacy provisions, prohibit disclosure of patient-identifiable information by most providers and health plans, except as authorized by the patient or explicitly permitted by legislation. Recent changes to the HIPAA regulations have strengthened considerably the requirements for security and privacy protections and have also given patients the right to pursue actions against both organizations and individuals when they feel that their personal information has been compromised. HIPAA also provides consumers with significant rights to be informed about how and by whom their health information will be used, and to inspect and sometimes amend their health information. Stiff criminal penalties including fines and possible imprisonment are associated with noncompliance or the knowing misuse of patient-identifiable information.

Computer systems can be designed to provide security, but only people can promote the trust necessary to protect the confidentiality of patients' clinical information. In fact, most breeches and inappropriate disclosures stem from human actions rather than from computer system failures. To achieve the goal of delivering coordinated and cost-effective care, clinicians need to access information on specific patients from many different locations. Unfortunately, it is difficult to predict in advance which clinicians will need access to which patient data and from which locations. Therefore, an HCIS must strike a balance between restricting information access and ensuring the accountability of the users of patient information. To build trust with its patients and meet HIPAA requirements, an HCO should adopt a three-pronged approach to securing information. First, the HCO needs to designate a security officer (and typically a privacy officer as well) and develop uniform security and confidentiality policies, including specification of sanctions, and to enforce these policies rigorously. Second, the HCO needs to train employees so they understand the appropriate uses of patient-identifiable information and the consequences of violations. Third, the HCO must use electronic tools such as

intrusion detection, access controls and audit trails not only to discourage misuse of information, but also to inform employees and patients that people who access confidential information without proper authorization or a "need to know", can be tracked and will be held accountable.

14.1.5 The Benefits of Health care Information Systems

On average, health care workers in administrative departments spend about three-fourths of their time handling information; workers in nursing units spent about one-fourth of their time on these tasks. The fact is that information management in health care organizations, even with significant computerization, is a costly activity. The collection, storage, retrieval, analysis, and dissemination of the clinical and administrative information necessary to support the organization's daily operations, to meet external and internal requirements for documentation and reporting, and to support short-term and strategic planning remain important and time-consuming aspects of the jobs of health-care workers.

Today, the justifications for implementing HCISs include cost reduction, productivity enhancement, and quality and service improvement, as well as strategic considerations related to competitive advantage and regulatory compliance (Vogel 2003):

- *Cost reduction*. Much of the historical impetus for implementing HCISs was their potential to reduce the costs of information management in hospitals and other facilities. HCOs continue to make tactical investments in information systems to streamline administrative processes and departmental workflow. Primary benefits that may offset some information-systems costs include reductions in labor requirements, reduced waste (e.g., dated surgical supplies that are ordered but unused or food trays that are delivered to the wrong destination and therefore are wasted), and more efficient management of supplies and other inventories. Large savings can be gained through efficient scheduling of expensive resources such as operating suites and imaging equipment. In addition, HCISs can help to eliminate inadvertent ordering of duplicate tests and procedures. Once significant patient data are available online, information systems can reduce the costs of storing, retrieving, and transporting charts in the medical-records department.
- *Productivity Enhancements*. A second area of benefit from an HCIS comes in the form of improved productivity of clinicians and other staff. With continuing (and at times increasing) constraints on reimbursements, HCOs are continually faced with the challenge of doing more with less. Providing information systems support to staff can in many cases enable them to manage a larger variety of tasks and data than would otherwise be possible using strictly manual processes. Interestingly, in some cases hospital investments in an HCIS support the productivity improvement of staff that are not employed by the hospital, namely the physicians, and can even extend to payers by lowering their costs. One of the major challenges with introducing a new HCIS is that the productivity of users may actually decrease in the initial months of the implementation. With complex clinical applications in particular, learning new ways of working can lead to high levels of user dissatisfaction in addition to lowered productivity.
- *Quality and service improvement*. As HCISs have broadened in scope to encompass support for clinical processes, the ability to improve the quality of care has become an additional benefit. Qualitative benefits of HCISs include improved accuracy and completeness of documentation, reductions in the time clinicians spend documenting (and associated increases in time spent with patients), fewer drug errors and quicker response to adverse events, and improved provider-to-provider communication. Through telemedicine and remote linkages (see Chap. 18), HCOs are able to expand their geographical reach and improve delivery of specialist care to rural and outlying areas. Once patient data are converted from a purely transaction format to a format better suited for

analytic work, the use of **clinical decision-support systems** in conjunction with a clinically focused HCIS can produce impressive benefits, namely improving the quality of care while reducing costs (Chap. 22) (Bates and Gawande 2003; James and Savitz 2011; Goldzweig, et al. 2009; Himmelstein and Woolhandler 2010; McCullough et al. 2010).

- *Competitive advantage*. Information technologies must be deployed appropriately and effectively; however, with respect to HCISs, the question is no longer whether to invest, but rather how much and what to buy. Although some organizations still attempt to cost justify all information-systems investments, many HCOs have recognized that HCISs are "**enabling technologies**" which means that the value comes not from the system itself but from what it "enables" the organization to do differently and better. If workflow and processes are not changed to take advantage of the technology, the value of the investment will largely go unrealized. And it is not just the ratio of financial benefits to costs that is important; access to clinical information is necessary not only to carry out patient management, but also to attract and retain the loyalty of physicians who care for (and thus control much of the HCO's access to) the patients. The long-term benefits of clinical systems include the ability to influence clinical practices by reducing large unnecessary variations in medical practices, to improve patient outcomes, and to reduce costs—although these costs might be more broadly economic and societal than related to specific reductions for the hospital itself (Leatherman et al. 2003, James and Savitz 2011). Physicians ultimately control the great majority of the resource-utilization decisions in health care through their choices in prescribing drugs, ordering diagnostic tests, and referring patients for specialty care. Thus, providing physicians with access to information on "best practices" based on the latest available clinical evidence, as well as giving them other clinical and financial data to make appropriate decisions, is an essential HCIS capability.
- *Regulatory compliance*. Health care is among the most heavily regulated industries in our economy. State and federal regulatory agencies perform a variety of oversight activities, and these require increasingly sophisticated and responsive HCISs to provide the necessary reports. For example, the Food and Drug Administration now mandates the use of barcodes on all drugs. Similarly, HIPAA rules specify the required content and format for certain electronic data transactions for those HCOs that exchange data electronically. OSHA, the Department of Labor, the Environmental Protection Agency, the Nuclear Regulatory Commission, and a host of other agencies all have an interest in seeing that the health care provided by HCOs is consistent with standards of safety and fairness.

14.1.6 Managing Information Systems in a Changing Health Care Environment

Despite the importance of integrated information systems, implementation of HCISs has proved to be a daunting task, often requiring a multiyear capital investment of tens (and at times, hundreds) of millions of dollars and forcing fundamental changes in the types and ways that health care professionals perform their jobs. To achieve the potential benefits, health organizations must plan carefully and invest wisely. The grand challenge for an HCO is to implement an HCIS that is sufficiently flexible and adaptable to meet the changing needs of the organization. Given the rapidly changing environment and the multiyear effort involved, people must be careful to avoid implementing a system that is obsolete functionally or technologically before it becomes operational. Success in implementing an HCIS entails consistent and courageous handling of numerous technical, organizational, and political challenges.

14.1.6.1 Changing Technologies

As we discussed in Chaps. 5 and 6, past decades have seen dramatic changes in computing and networking technologies. These advances are

important in that they allow quicker and easier information access, less expensive computational power and data storage, greater flexibility, and other performance advantages. A major challenge for many HCOs is how to decide whether to support a best of breed strategy, with its requirement either to upgrade individual systems and interfaces to newer products or to migrate from their patchwork of legacy systems to a more integrated systems environment. Such migration requires integration and selective replacement of diverse systems that are often implemented with closed or nonstandard technologies and medical vocabularies. Unfortunately the trade-off between migrating from best of breed to more integrated systems is that vendors offering more integrated approaches seldom match the functionality of the best of breed environment. However, this strategy is becoming less of an option since commercial vendors are broadening and deepening the scope of their application suites in order to minimize the challenges of building and managing interfaces and to protect their market share. In a sense, it is the information content of the systems and the ability to implement them that is much more important than the underlying technology—as long as the data are accessible, the choice of specific technology is less critical.

14.1.6.2 Changing Culture

In the current health care environment, physicians are confronted with significant obstacles to the practice of medicine as they have historically performed it. With a long history of entrepreneurial practice, physicians face significant adjustments as they are confronted by pressures to practice in accordance with institutional standards aimed at reducing variation in care, and to focus on the costs of care even when those costs are borne either by hospitals or by third party payers. They are expected to assume responsibility not simply for healing the sick, but for the wellness of people who come to them not as patients but as members of health plans and health maintenance organizations. In addition, they must often work as members of collaborative patient-care teams. The average patient length of stay in a hospital is decreasing; at the same time, the complexity of the care provided both during and after discharge is increasing. The time allotted for an individual patient visit in an ambulatory setting is decreasing as individual clinicians face economic incentives to increase the number of patients for whom they care each day. Some HCOs, aided by federal funding incentives, are now instituting **pay-for performance** incentives to reward desired work practices. At the same time, it is well known that the amount of knowledge about disease diagnosis and treatment increases significantly each year, with whole new areas of medicine being added from major breakthroughs in areas such as genomic and imaging research. To cope with the increasing workload, greater complexity of care, extraordinary amounts of new medical knowledge, new skills requirements, and the wider availability of medical knowledge to consumers through the Internet, both clinicians and health executives must become more effective information managers, and the supporting information systems must meet their workflow and information requirements. As the health care culture and the roles of clinicians and health executives continue to change, HCOs must constantly reevaluate the role of information technology to ensure that the implemented systems continue to match user requirements and expectations.

14.1.6.3 Changing Processes

Developing a new vision of how health care will be delivered and managed, designing processes and implementing supporting information systems are all critical to the success of evolving HCOs. Changes in process affect the jobs that people do, the skills required to do those jobs, and the fundamental ways in which they relate to one another. For example, models of care management that cross organizational or specialty boundaries encourage interdisciplinary care teams to work in harmony to promote health as well as treat illness. Although information systems are not the foremost consideration for people who are redesigning processes, a poor information-systems implementation can institutionalize bad processes.

HCOs periodically undertake various process redesign initiatives (following models such as **Six Sigma** or **LEAN**), and these initiatives can lead to fundamental transformations of the enterprise. Indeed, work process redesign is essential if information systems are to become truly valuable "enablers" in HCOs. Too often, however, the lack of a clear understanding of existing organizational dynamics leads to a misalignment of incentives—a significant barrier to change—or to the assumption that simply installing a new computer system will be sufficient to generate value. Moreover, HCOs, like many organizations, are collections of individuals who often have natural fears about and resistance to change. Even under the best of circumstances, there are limits to the amount of change that any organization can absorb. The magnitude of work required to plan and manage organizational change is often underestimated or ignored. The handling of people and process issues has emerged as one of the most critical success factors for HCOs as they implement new work methods and new and upgraded information systems.

14.1.6.4 Management and Governance

Figure 14.6 illustrates the information-technology environment of an HCO composed of two hospitals, an owned physician practice, affiliated nursing homes and hospice, and several for-profit service organizations. Even this relatively simple environment presents significant challenges for the management and governance of information systems. For example, to what extent will the information management function be controlled centrally versus decentralized to the individual operating units

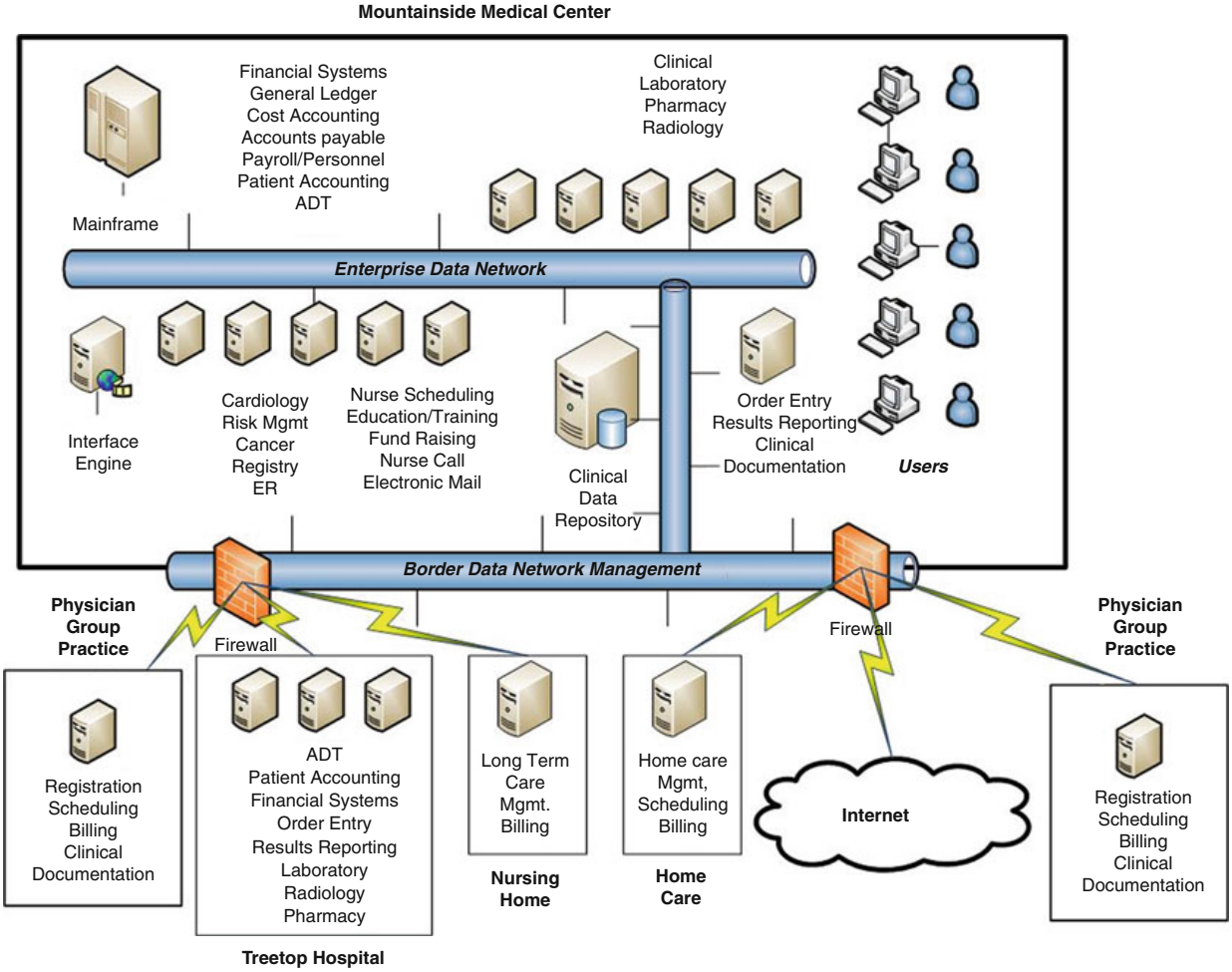

Fig. 14.6 An example of an information systems environment for a small integrated delivery network (IDN). Even this relatively simply IDN has a complex mix of information systems that pose integration and information management challenges for the organization

and departments? How should limited resources be allocated between new investment in strategic projects (such as office-based data access for physicians) and the often critical operational needs of individual entities (e.g., replacement of an obsolete laboratory information system)? Academic medical centers with distinct research and educational needs raise additional issues for managing information across operationally independent and politically powerful constituencies.

Trade-offs between functional and integration requirements, and associated contention between users and information-systems departments, will tend to diminish over time with the development and widespread adoption of technology standards and common clinical-data models and vocabulary. On the other hand, an organization's information-systems "wants" and "needs" will always outstrip its ability to deliver these services. Political battles will persist, as HCOs and their component operating units wrestle with the age-old issues of how to distribute scarce resources among competing, similarly worthy projects.

A formal HCIS governance structure with representation from all major constituents provides a critical forum for direction setting, prioritization, and resource allocation across an HCO. Leadership by respected clinical peers has proved a critical success factor for clinical systems planning, implementation, and acceptance. In addition, the creation of an Information Systems Advisory or Steering Committee composed of the leaders of the various constituencies within the HCO, can be a valuable exercise if the process engages the organization's clinical, financial, and administrative leadership and users and results in their gaining not only a clear understanding of the highest-priority information technology investment requirements but also provides a sense of accountability and ownership over the HCISs and their various functions (Vogel 2006). This supports one of the principles of information technology governance: *how* an institution makes IT investment decisions is often more important than *what* specific decisions are made (Weill and Ross 2004). Because of the dynamic nature of both health care business strategies and the supporting technologies, many HCOs have seen the timeframes of their strategic information-management thinking shrink from 5 years to three, and then be changed yet again through annual updates.

14.2 Functions and Components of a Health Care Information System

Carefully designed computer-based information systems can increase the effectiveness and productivity of health professionals, improve the quality and reduce the costs of health services, and improve levels of service and of patient satisfaction. As described in Sect. 14.1, the HCISs support a variety of functions, ranging from the delivery and management of patient care to the administration of the health organization. From a functional perspective, HCISs typically consist of components that support five distinct purposes: (1) patient management and billing, (2) ancillary services, (3) care delivery and clinical documentation, (4) clinical decision support, (5) institutional financial and resource management.

14.2.1 Patient Management and Billing

Systems that support patient management functions perform the basic HCO operations related to patients, such as registration, scheduling, admission, discharge, transfer among locations, and billing. Historically within HCOs, maintenance of the hospital census and a patient billing system were the first tasks to be automated—largely because a patient's location determined not only the daily room/bed charges (since an ICU bed was more expensive than a regular medical/surgical bed) but where medications were to be delivered, and where clinical results were to be posted. Today, virtually all hospitals and ambulatory centers and many physician offices use a computer-based **master patient index** (**MPI**) to store patient-identification information that is acquired during the patient-registration process, and link to simple encounter-level information such as dates and locations where

services were provided. The MPI can also be integrated within the registration module of an ambulatory care or physician-practice system or even elevated to an **enterprise master patient index** (**EMPI**) across several facilities. Within the hospital setting, the census is maintained by the **admission–discharge–transfer** (**ADT**) module, which is updated whenever a patient is admitted to the hospital, discharged from the hospital, or transferred from one bed to another.

Registration and patient census data serve as a reference base for the financial programs that perform billing functions. When an HCIS is extended to other patient-care settings—e.g., to the laboratory, pharmacy, and other ancillary departments—patient-management systems provide a common reference base for the basic patient demographic data needed by these systems. Without access to the centralized database of patient financial, demographic, registration and location data, these subsystems would have to maintain duplicate patient records. In addition, the transmission of registration data can trigger other activities, such notification of hospital housekeeping when a bed becomes available after a patient is discharged. The billing function in these systems serves as a collection point for all of the chargeable patient activity that occurs in a facility, including room/bed charges, ancillary service charges, and supplies used during a patient's stay.

Scheduling in a health care organization is complicated because patient load and resource utilization can vary by day, week, or season or even through the course of a single day simply due to chance, emergencies that arise, or to patterns of patient and physician behavior. Effective resource management requires that the appropriate resources be on hand to meet such fluctuations in demand. At the same time, resources should not remain unnecessarily idle since that would result in their inefficient use. The most sophisticated scheduling systems have been developed for the operating rooms and radiology departments, where scheduling challenges include matching the patient not only with the providers but also with special equipment and support staff such as technicians. **Patient-tracking applications** monitor patient movement in multistep processes; for example, they can monitor and manage patient wait times in the emergency department.

Within a multi-facility HCO, the basic tasks of patient management are compounded by the need to manage patient care across multiple settings, some of which may be supported by independent information systems. Is the Patricia C. Brown who was admitted last month to Mountainside Hospital the same Patsy Brown who is registering for her appointment at the Seaview Clinic? Integrated delivery networks ensure unique patient identification either through conversion to common registration systems or, more frequently, through implementation of an enterprise EMPI (see Sect. 14.4) that links patient identifiers and data from multiple registration systems.

14.2.2 Ancillary Services

Ancillary departmental systems support the information needs of individual clinical departments within an HCO. From a systems perspective, those areas most commonly automated are the laboratory, pharmacy, radiology, blood-bank, operating rooms, and medical-records departments, but can also include specialized systems to support cardiology (for EKGs), respiratory therapy and social work. Such systems serve a dual purpose within an HCO. First, ancillary systems perform many dedicated tasks required for specific departmental operations. Such tasks include generating specimen-collection lists and capturing results from automated laboratory instruments in the clinical laboratory, printing medication labels and managing inventory in the pharmacy, and scheduling examinations and supporting the transcription of image interpretations in the radiology department. In addition, information technology coupled with robotics can have a dramatic impact on the operation of an HCO's ancillary departments, particularly in pharmacies (to sort and fill medication carts) and in clinical laboratories (where in some cases the only remaining manual task is the collection of the specimen and its transport to the laboratory's robotic system). Second, the ancillary systems contribute major

data components to online patient records, including laboratory-test results and pathology reports, medication profiles, digital images (see Chap. 20), records of blood orders and usage, and various transcribed reports including history and physical examinations, operating room and radiology reports. HCOs that consolidate ancillary functions outside hospitals to gain economies of scale—for example, creating outpatient diagnostic imaging centers and reference laboratories—increase the complexity of integrated patient management, financial, and billing processes.

14.2.3 Care Delivery and Clinical Documentation

Electronic health record (EHR) systems that support care delivery and clinical documentation are discussed at length in Chap. 12. Although comprehensive EHRs are the ultimate goal of most HCOs, many organizations today are still building more basic clinical-management capabilities. Automated **order entry** and **results reporting** are two important functions provided by the clinical components of an HCIS. Health professionals can use the HCIS to communicate with ancillary departments electronically, eliminating the easily misplaced paper slips or the transcription errors often associated with translating hand-written notes into typed requisitions, thus minimizing delays in conveying orders. The information then is available online, where it is easily accessible by any authorized health professional that needs to review a patient's medication profile or previous laboratory-test results. Ancillary departmental data represent an important subset of a patient's clinical record. A comprehensive clinical record, however, also includes various data that clinicians have collected by questioning and observing the patient, including the history and physical report, progress notes and problem lists. In the hospital, an HCIS can help health personnel perform an initial assessment when a patient is admitted to a unit, maintain patient-specific care plans, chart vital signs, maintain medication-administration records, record diagnostic and therapeutic information, document patient and family teaching, and plan for discharge (also see Chap. 15). Many organizations have developed diagnosis-specific **clinical pathways** that identify clinical goals, interventions, and expected outcomes by time period. Using clinical pathways, case managers or care providers can document actual versus expected outcomes and are alerted to intervene when a significant unexpected event occurs. More hospitals are now implementing systems to support what are called **closed loop medication management systems** in which every task from the initial order for medication to its administration to the patient is recorded in an HCIS—one outcome of increased attention to patient safety issues.

With the shift toward delivering more care in outpatient settings, clinical systems have become more common in ambulatory clinics and physician practices. Numerous vendors have introduced **smart phones**, **tablets**, and other mobile devices with software designed specifically for physicians in ambulatory settings, so that they can access appropriate information even as they move from one exam room to another. Such systems allow clinicians to record problems and diagnoses, symptoms and physical examinations, medical and social history, review of systems, functional status, active and past prescriptions, provide access to therapeutic and medication guidelines, etc. The most successful systems are integrated with a practice management system, providing additional support for physician workflow and typical clinic functions, for example, by documenting telephone follow-up calls or printing prescriptions. In addition, specialized clinical information systems have been developed to meet the specific requirements of intensive-care units (see Chap. 19), long-term care facilities, home-health organizations, and specialized departments such as cardiology and oncology.

14.2.4 Clinical Decision Support

Clinical decision-support systems (Chap. 22) directly assist clinical personnel in data interpretation and decision-making. Once the basic clinical components of an HCIS are well developed, clinical decision-support systems can use

the information stored there to monitor patients and issue alerts, to make diagnostic suggestions, to provide limited therapeutic guidance, and to provide information on medication costs. These capabilities are particularly useful when they are integrated with other information-management functions. For example, a useful adjunct to **computer-based physician order-entry** (**CPOE**) is a decision-support program that alerts physicians to patient food or drug allergies; helps physicians to calculate patient-specific drug-dosing regimens; performs advanced order logic, such as recommending an order for prophylactic antibiotics before certain surgical procedures; automatically discontinues drugs when appropriate or prompts the physician to reorder them; suggests more cost-effective drugs with the same therapeutic effect; or activates and displays applicable clinical-practice guidelines (see Chap. 22). **Clinical-event monitors** integrated with results-reporting applications can alert clinicians to abnormal results and drug interactions by electronic mail, text message or page. In the outpatient setting, these event monitors may produce reminders to provide preventive services such as screening mammograms and routine immunizations. The same event monitors might trigger access to the HCO's approved formulary, displaying information that includes costs, indications, contraindications, approved clinical guidelines, and relevant online medical literature (Perreault and Metzger 1999; Teich et al. 1997; Kaushal et. al. 2003).

14.2.5 Financial and Resource Management

Financial and administrative systems assist with the traditional business functions of an HCO, including management of the payroll, human resources, general ledger, accounts payable, and materials purchasing and inventory. Most of these data-processing tasks are well structured, and have been historically labor intensive and repetitious—ideal opportunities for substitution with computers. Furthermore, with the exception of patient-billing functions, the basic financial tasks of an HCO do not differ substantially from those of organizations in other industries. Not surprisingly, financial and administrative applications have typically been among the first systems to be standardized and centralized in IDNs.

Conceptually, the tasks of creating a patient bill and tracking payments are straightforward, and financial transactions such as claims submission and electronic funds transfer have been standardized to allow **electronic data interchange** (**EDI**) among providers and payers. In operation, however, patient accounting requirements are complicated by the myriad and oft-changing reimbursement requirements of government and third-party payers. These requirements vary substantially by payer, by insurance plan, by type of facility where service was provided, and often by state. As the burden of financial risk for care has shifted from third party payers to providers (through **per diem** or **diagnosis-based reimbursements**), these systems have become even more critical to the operation of a successful HCO. As another example, managed care contracts add even more complexity, necessitating processes and information systems to check a patient's health-plan enrollment and eligibility for services, to manage referrals and preauthorization for care, to price claims based on negotiated contracts, and to create documentation required to substantiate the services provided.

As HCOs increasingly go "at risk" for delivery of health services by negotiating **per diem**, **diagnosis-based**, **bundled** and **capitated payments**, their incentives need to focus not only on reducing the cost per unit service but also on maintaining the health of members while using health resources effectively and efficiently. Similarly, the HCO's scope of accountability broadens from a relatively small population of sick patients to a much larger population of plan members (such as might be found in ACOs), most of whom are still well.

Provider-profiling systems support utilization management by tracking each provider's resource utilization (costs of drugs prescribed, diagnostic tests and procedures ordered, and so on) compared with severity-adjusted outcomes of that provider's patients such as their rate of hospital readmission and mortality by diagnosis.

Such systems are also being used by government bodies and consumer advocate organizations as they publicize their findings, often through the Internet. **Contract-management systems** have capabilities for estimating the costs and payments associated with potential managed care contracts and comparing actual with expected payments based on the terms of the contracts. More advanced managed-care information systems handle **patient triage** and medical management functions, helping the HCOs to direct patients to appropriate health services and to proactively manage the care of chronically ill and high-risk patients. Health plans, and IDNs that incorporate a health plan, also must support payer and insurance functions such as claims administration, premium billing, marketing, and member services.

14.3 Historical Evolution of the Technology of Health care Information Systems (HCISs)

Technological advances and changes in the information and organizational requirements of HCOs have driven many of the changes in system architecture, hardware, software, and functionality of HCISs over time. The tradeoff between functionality and ease of integration is another important factor that accounts for choices that vendors have made in systems design (see Fig. 14.7).

14.3.1 Central and Mainframe-based Systems

The earliest HCISs (typically found in hospitals) were designed according to the philosophy that a single comprehensive or **central computer system** could best meet an HCO's information processing requirements. Advocates of the centralized approach emphasized the importance of first identifying all the hospital's information needs and then designing a single, unified framework to meet these needs. As we have seen, patient management and billing functions were the initial focus of such efforts. One result of this design goal was the development of systems in which a single, large computer performed all information processing and managed all the data files using application-independent file-management programs—although focusing almost exclusively on financial and billing data. Users accessed these systems via general-purpose **video-display terminals** (**VDTs**) affectionately known as "green screens" because the displayed numbers and text were often green on a dark background.

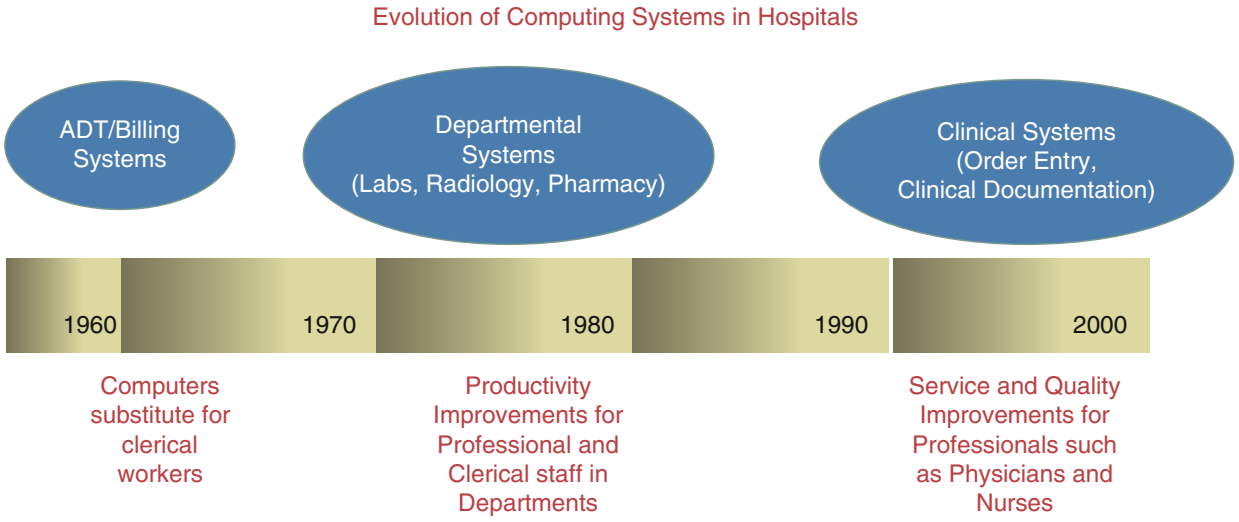

Fig. 14.7 The evolution of computing systems in hospitals has followed a path that parallels the evolution of computing systems in general. From mainframes to minicomputers to desktops, and more recently mobile devices, the purpose and function of systems in hospitals has followed a path from financial systems to departmental systems to systems designed specifically to enhance the productivity and raise the quality of health care services

One of the first clinically-oriented HCISs was the Technicon Medical Information System. System development began in 1965 as a collaborative project between the Lockheed Corporation and El Camino Hospital, a community hospital in Mountain View, California. By 1987, the system had been installed in more than 85 institutions by Technicon Data Systems (TDS), which had purchased the system from Lockheed in 1971. TDS was one of the earliest examples of a large, centrally operated, and clinically focused HCIS. Depending on the size of the central machine, the TDS center could support from several hundred to a few thousand hospital beds. Because of this high capacity, one computer installation could serve multiple hospitals in an area. The hospitals were connected via high-speed dedicated telephone lines linked to the central computer. Within a hospital, a switching station connected the telephone lines to an onsite network connecting to stations on every patient-care unit. Each unit had at least one VDT and one printer which enabled users to display, and print patient information. Initially, TDS sold proprietary terminals, printers, light pens and even implemented their own data transmission protocols, but as more general purpose PCs became prominent and data networking protocols more standardized, the proprietary nature of the system diminished to where the focus was entirely on the software. Because the TDS system was designed for use by both nurses and physicians it was one of the first systems to support both nursing clinical documentation and physician order entry.

The Center for Clinical Computing (CCC) system, developed by Howard Bleich and Warner Slack as a centralized clinical computing system, was first deployed in 1978 at the Beth Israel Medical Center in Boston (now part of the Beth Israel Deaconess Medical Center and the CareGroup IDN). Still in operation, this system is designed around a single common registry of patients, with tight integration of all its departmental systems. It was remarkable in the breadth of its functionality to support physicians and the intensity of its use by clinicians. It was the first system to offer hospital-wide electronic mail, as well as end-user access to Medline via PaperChase. In addition, CCC was among the first to employ audit trails on who was looking at patient data, a feature now common in clinical systems (and a HIPAA requirement). In ambulatory clinics, an electronic patient record including support for problem lists, clinic notes, prescription writing, and other functions supported over 1,000 clinicians in more than 30 primary-care and specialty areas (Safran et al. 1991). On the other hand, the system provided only limited support for order entry, alerts, and reminders. The CCC also featured a MUMPS database functioning as a clinical-data repository and an online data warehouse, called ClinQuery (Safran et al. 1989) with complete data on all test results and medications, as well as **ICD-9-CM** and **SNOMED** diagnosis codes. The CCC was transferred to the Brigham and Women's Hospital in 1983 and was subsequently developed separately as the Brigham Integrated Computer System (BICS), a distributed client–server system. In 2012, Partners Health care, of which Brigham and Women's Hospital is a member organization, made the decision to replace BICS and other in-house developed systems with a commercial vendor product.

Central systems integrated and communicated information well because they provided users with a centralized data store and a single, standardized method to access information simply and rapidly. On the other hand, the biggest limitation of central systems was their inability to accommodate the diverse needs of individual departments. There is a tradeoff between the uniformity (and relative simplicity) of a generalizable system and the nonuniformity and greater responsiveness of custom-designed systems that solve specific problems. Generality—a characteristic that enhances communication and data integration in a homogeneous environment—can be a drawback in an HCO because of the complexity and heterogeneity of the information-management tasks. In general, central systems have proved too unwieldy and inflexible to support current HCO requirements, except in smaller facilities. The development of smaller but powerful computing platforms subsequently led to software development that focused more on specific departmental requirements.

14.3.2 Departmental Systems

By the 1970s, departmental systems began to emerge. Decreases in the price of hardware and improvements in software made it feasible for individual departments within a hospital to acquire and operate their own computers. In a **departmental system**, one or a few computers can be dedicated to processing specific functional tasks within the department. Distinct software application modules carry out specific tasks, and a common framework, which is specified initially, defines the interfaces that will allow data to be shared among the modules. Radiology (Chap. 20) and Laboratory systems are examples of this type of system.

The most ambitious project based on the departmental approach was the Distributed Hospital Computer Program (DHCP) for the Veterans Administration (VA) hospitals which was initially announced in 1982, although based on work begun at the VA in the 1970s. The system had a common database (Fileman), which was written to be both hardware- and operating-system-independent. A small number of support centers in the VA developed the software modules in cooperation with user groups. The CORE—the first set of applications to be developed and installed—consisted of modules for patient registration, ADT, outpatient scheduling, laboratory, outpatient pharmacy, and inpatient pharmacy. Modules to support other clinical departments (such as radiology, dietetics, surgery, nursing, and mental health) and administrative functions (such as financial and procurement applications) were developed subsequently. By 1985, the VA had installed DHCP in more than one-half of its approximately 300 hospitals and clinics. The software was in the public domain and was also used in private hospitals and other government facilities (Kolodner and Douglas 1997). Interestingly, one of the reasons for the success of the VA system was its ability to focus on the clinical environment. Given the nature of government reimbursement for the care of veterans at the time, there was no need to develop or integrate a billing function into the DHCP system.

The departmental approach responded to many of the challenges of central systems. Although individual departmental systems are constrained to function with predefined interfaces, they do not have to conform to the general standards of an overall system, so they can be designed to accommodate the special needs of specific areas. For example, the processing capabilities and file structures suitable for managing the data acquired from a patient-monitoring system in the intensive-care unit (analog and digital signals acquired in real time) differ from the features that are appropriate for a system that reports radiology results (text storage and text processing). Furthermore, modification of departmental systems, although laborious with any approach, is simpler because of the smaller scope of the system. The price for this greater flexibility is increased difficulty in integrating data and communicating among modules of the HCISs. In reality, installing a subsystem is never as easy as simply plugging in the connections.

Also in the early 1980s, researchers at the University of California, San Francisco (UCSF) Hospital successfully implemented one of the first **Local Area Networks** (**LANs**) to support communication among several of the hospital's standalone systems in the early 1980s. Using technology developed at the Johns Hopkins University, they connected minicomputers that supported patient registration, medical records, radiology, the clinical laboratory, and the outpatient pharmacy. Interestingly, each of the four computer systems was different from the other three: the computers were made by different manufacturers and ran different operating systems (McDonald, Wiederhold et al. 1984a) but were able to communicate with each other through standardized communications protocols.

By the late1980s, HCISs based on evolving network-communications standards were being developed and implemented in HCOs. As **distributed computer systems**, connected through electronic networks, these HCISs consisted of a federation of independent systems that had been tailored for specific application areas. The computers operated autonomously and shared data (and sometimes programs and other resources,

such as printers) by exchanging information over a local area network (LAN; see Chap. 5) using standard protocols such as **TCP/IP** and Health Level 7(HL7) for communication and in many cases utilizing the interface engine strategy we discussed earlier in Sect. 14.1.1.

The University of Michigan Hospital in Ann Arbor later adopted a hybrid strategy to meet its information needs. The hospital supported a central model of architecture and operated a mainframe computer to perform core HCIS functions. In 1986, however, it installed a local area network (LAN) to allow communication among all its internal clinical laboratories and to allow physicians to obtain laboratory-test results directly from the laboratory information system. At the time of installation, more than 95 % of all the peripheral devices in the laboratories were connected to the network rather than hardwired directly to the laboratory computer. A second clinical host computer, which supported the radiology information system, was later added to the LAN, allowing physicians to access radiology reports as well. Although the mainframe HCIS initially was not connected to the LAN, the hospital later adopted the strategy of installing universal workstations that could access both the mainframe computer and the clinical hosts via the LAN (Friedman and Dieterle 1987).

One advantage of LAN-connected distributed systems was that individual departments could have greater flexibility in choosing hardware and software that optimally suited their specific needs. Even smaller ancillary departments such as Respiratory Therapy, which previously could not justify a major computer acquisition, could now purchase microcomputers and participate in the HCIS environment. Health care providers in nursing units or at the bedside, physicians in their offices or homes, and managers in the administrative offices could eventually access and analyze data locally using what were initially termed microcomputers (later known as desktop personal computers or PCs). On the downside, the distribution of information processing capabilities and responsibility for data among diverse systems made the tasks of data integration, communication, and security more difficult—a fact that continues to the present day. Development of industry-wide standard network and interface protocols such as TCP/IP and HL7 has eased the technical problems of electronic communication considerably. Still, there are problems to overcome in managing and controlling access to a patient database that is fragmented over multiple computers, each with its own file structure and method of file management. Furthermore, when no global architecture or vocabulary standards are imposed on the HCISs, individual departments and entities may encode data values in ways that are incompatible with the definitions chosen by other areas of the organization. The promise of sharing among independent departments, entities, and even independent institutions has increased the importance of defining clinical data standards (see Chap. 7). As noted earlier, some HCOs pursue a best of breed strategy in which they choose the best system, regardless of vendor and technology, then work to integrate that system into their overall HCIS environment. Some HCOs modify this strategy by choosing suites of related applications (e.g., selecting all ancillary systems from a single vendor, also known as **best of cluster**), thereby reducing the overall number of vendors they work with and, in theory, reducing the costs and difficulty of integration. Commercial software vendors have supported this strategy by broadening their offerings of application suites and managing the integration at the suite level rather than at the level of individual applications. Cerner and Epic are examples of clinical systems vendors who have pursued this strategy, and Oracle's PeopleSoft and Lawson are examples on the financial/administrative side.

The complexity and variety of information processing requirements across today's HCOs and IDNs, means that some level of distributed architecture is often required. Simply put, no single vendor has been able to develop and implement applications that support the entire range of an HCO's information processing requirements. So in general, all large commercial systems support some type of distributed model. PC-based universal workstations are the norm as well. In fact, some HCOs and IDN's now support thousands of PCs in enterprise-wide networked environments. The

requirement for direct access to independent ancillary systems has been largely eliminated not only by enterprise data networks, but by interfaces that join such systems to a core clinical system or a centralized clinical data repository that receives clinical data from each ancillary system. For example, whereas staff working in the laboratory may access the laboratory system directly, clinicians may view all clinical results (laboratory, radiology, and so on) stored in a centralized **clinical data repository**. The ability to access patient databases (by clinicians), human resources documents (by employees), financial information (by administrators) and basic information about facilities, departments, and staff (by the public) is enabled through a single enterprise-wide data network (See Fig. 14.3).

14.3.3 Integrated Systems from Single Vendors

Many smaller HCOs have opted for implementation of turnkey systems, in which commercial vendors have bundled a number of functional capabilities into a single application suite (MEDITECH is a good example of this type of offering).

These systems offer a way to achieve reasonable function and integration, although they typically permit minimal customization to meet institution-specific workflows and requirements. In addition, they may not have the depth of specialized functions compared to systems designed for specific departmental functions. Numerous debates have been held at national conferences regarding the desirability of an integrated system versus best of breed approaches in which the various systems have to be interfaced in order to function. In the late 1990s, several large IDNs developed their IT strategies based on the use of integrated systems from vendors historically focused on smaller hospitals. This provided greater credibility to these vendors and at the same time challenged the long held assumption that the greater functionality of best of breed strategies, with their inherently greater cost and interface requirements, is the only viable strategy for large IDNs.

14.4 Architecture for a Changing Environment

As the complexity of the health care business continues to increase, HCOs and IDNs present new challenges to information systems developers. As we described in Sect. 14.1, most IDNs have developed through the merger or acquisition of independent organizations. Thus, the information systems environment of a new or evolving IDN can be a jumble of disparate legacy systems, technologies, and architectures. In such an environment, the challenge is for the IDN's information systems team to configure systems and processes to support new business strategies (such as a diabetes management program or a central call center) and provide integrated information access throughout the IDN, while maintaining uninterrupted operational support for the IDN's existing business units, and do so within the financial constraints of reimbursement levels that seem to decline almost annually.

Sometimes, an IDN will selectively replace specific systems to fit its new organizational structure and strategies (e.g., consolidation of the finance and human resources departments and migration to common corporate general ledger, accounts payable, payroll, and human resources systems for all business entities). As always, resources (both money and staff) are limited; and often it is simply not feasible for an IDN to replace all legacy systems with new common systems, so specific HCISs may remain relatively isolated for long periods of time.

Legacy systems environments and business strategies in both large HCOs and IDNs present unique information challenges. Nonetheless, a few lessons can be learned from past efforts. First, a strategy for data preservation must be developed by providing access to data and implementing an approach for standardizing the meaning of those data. Second, to the extent possible, IDNs and HCOs should separate three conceptual layers—data management, applications and business logic, and user interface—to allow greater flexibility (See Fig. 14.8).

The first layer of architecture is the **data layer**. Data—the results of transactions that the

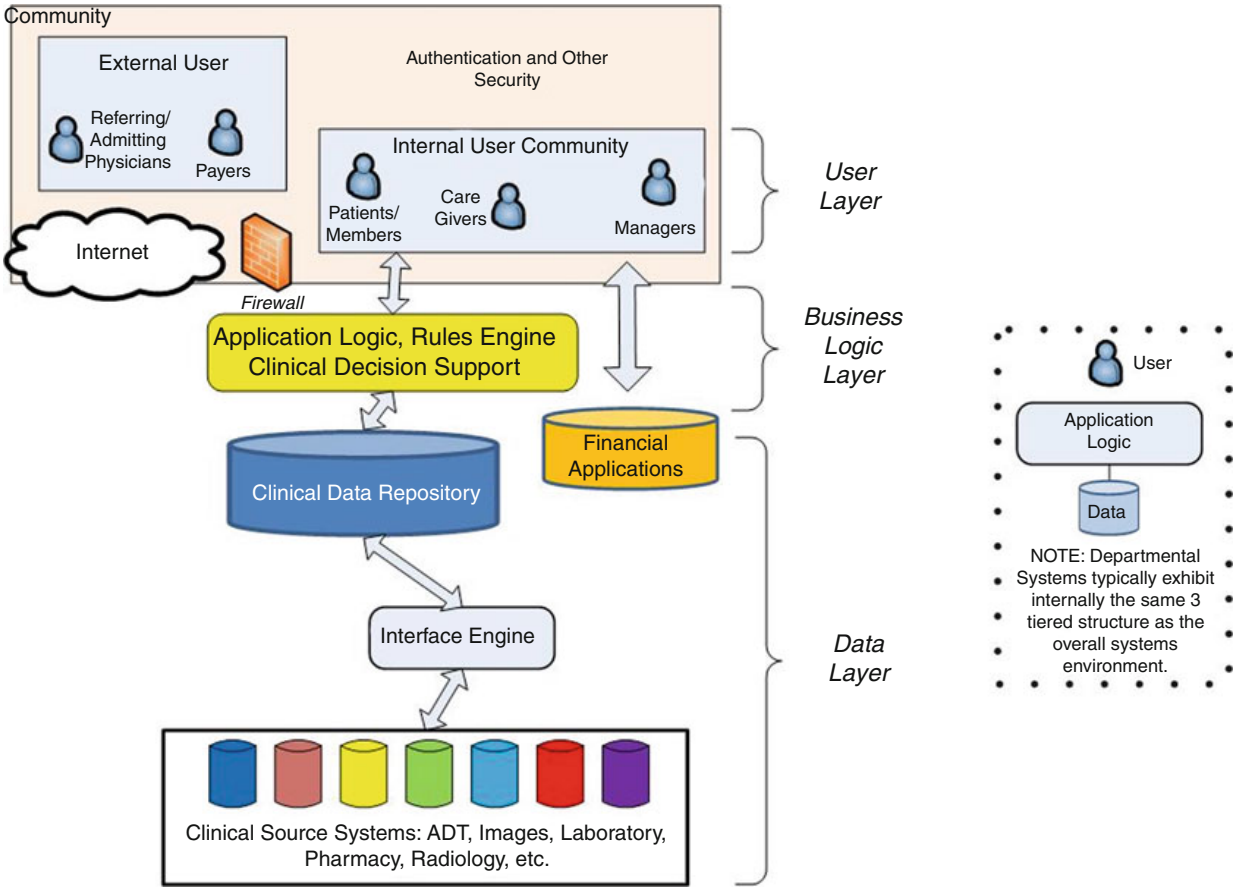

Fig. 14.8 Three conceptual layers of an information systems architecture illustrate the separation that occurs among the data, business logic and presentation layers. Over time, changes in the presentation and business logic layers may be made while retaining the data layer. As noted in the figure, the three layers can typically be found even within a single application (e.g., a laboratory or radiology system)

HCO generates—are of central importance. One fundamental mistake that a health care organization can make is to fail to provide access to its data. Organizations that choose information systems based on the functionality available to meet short-term needs may find that these needs are no longer as important as the HCO or IDN continues to evolve. For this reason, a long-term data strategy needs to be a separate component of the information-management plan. This plan must include access to data for applications and a method to ensure that demographic, clinical, and financial data collected across business units are consistent and comparable. Security and confidentiality safeguards (see Sect. 14.1.4) should also be part of the data strategy.

With respect to clinical data, HCOs and IDNs need data for both real-time operations and retrospective data analysis. These needs generate different requirements for data management. In the first case, detailed data need to be stored and optimized for retrieval for the individual patient. In the second case, the data need to be optimized for aggregation across a population of patients. Although the terms are sometimes used interchangeably, the distinction should be made between a **clinical data repository** (**CDR**), which typically stores "transaction" data and serves the needs of patient care and day-to-day operations, and an **enterprise information warehouse** (**EIW**) which serves as the foundation for analytic tasks for both retrospective and longer term business and clinical planning such as contract management and outcomes evaluation. Both the CDR and data warehouse should be purchased or developed for their ability to model, store, and retrieve efficiently the organization's data. Quite often, vendors of a CDR or

warehouse include programs to view and manipulate these data. Conceptually, this packaging makes sense.

The second component of a clinical data strategy is an ability to keep patient information comparable. At the simplest level one needs to uniquely identify each patient. When a health organization consisted of only one hospital and one major information system, the authority over patient identification was relatively simple and usually resided in the HCIS's admitting or registration module (see Sect. 14.2.1). As HCOs evolve into IDNs, there is no one authority that can identify the patient or resolve a conflicting identification. Thus, as we noted earlier, a new architectural component, the enterprise master patient index (EMPI), has arisen as the **name authority**. In its simplest form, the EMPI is an index of patient names and identification numbers used by all information systems in the IDN that store a patient registry. Using this type of EMPI requires considerable manual intervention to ensure data synchrony, but it does enable an IDN to uniquely identify its patients and link their data. Alternatively, an EMPI can be configured as the name authority for all systems that hold patient information even within a single HCO. Then each system must interact with the EMPI in order to get a patient-identification number assigned. This type of EMPI requires that all other systems disable their ability to assign identification numbers and use the external—and unique—EMPI-generated identification numbers.

Uniquely identifying patients within the HCO and the IDN is just a necessary first step in ensuring data comparability and consistency. Health care providers also may want to know which of their patients are allergic to penicillin, which patients should be targeted for new cardiac-disease prevention services, or which patients are likely to need home services when they are discharged from the hospital or emergency room. To store and evaluate the data that could be used to make such determinations, a consistent approach must be developed for naming data elements and defining their values (see Chaps. 7 and 8). Some institutions, such as Columbia University Medical Center (CUMC) in New York City, have developed their own internal vocabulary standards, or **terminology authority**. CPMC separates the storage and retrieval of data from the meaning of the terms in the database using a **medical entities dictionary** that defines valid database terms and synonyms for use by its clinical applications. An alternative approach is to develop a set of **terminology services**. These services fall into three categories: (1) linking or normalizing the data contained within the HCO's or IDN's legacy databases before these data are copied to a CDR; (2) reregistering all terms used by new applications and linking them to external authoritative vocabulary terms, such as those contained within the Unified Medical Language System's **Metathesaurus** (see Chap. 8); and (3) providing real-time help in selecting the appropriate term to describe a clinical situation.

The second layer of architecture is the **business logic layer**. As we discussed in Sect. 14.1.6, once a system has been installed, its users will usually resist change. The reason for this inertia is not just that there is a steep learning curve for a new system but also that historical systems embody institutional workflow. Separating the workflow or business logic from the database will enable more natural migrations of systems as the HCO or IDN evolves. Organizations should not, however, assume that old workflow is correct or should necessarily be embodied in new information systems. The point here is that a modern architecture that separates the workflow from the data allows prior data to be carried forward as the systems migrate. This also enables organizations to change workflow as new features and functions become available in newer products or product releases.

The third layer, the **user-interface layer**, is how users "see" the data, and most often the layer most subject to frequent change. The cost of desktop devices and support represents a significant portion of HCO and IDN information systems budgets—often as much as one-third of the total budget. For example, an IDN that supports 10,000 workstations will incur ongoing costs for hardware and software alone of close to $10 million per year, assuming a $3,000 unit cost and a

3-year life span per workstation. **Thin clients**, and **web-based technologies**, which minimize processing at the workstation level, can substantially reduce this cost by allowing simpler maintenance and support as well as decreased cost per device.

Future network and computer systems architectures such as **Services Oriented Architecture** (**SOA**) will likely increasingly rely on the tools and technological developments driven by the ubiquity of the Internet. Smart phones, tablets, **pagers** and other mobile devices continue to shrink in size while increasing in functionality. However, often due to size limitations (and specifically the **form factor** limits of keyboards and display screens available on smaller devices), these systems are currently better suited for one-way retrieval and presentation of information and do not adequately support clinicians' requirements for data input where free text entry continues to be used. But even with shrinking size, these devices are still suitable for accessing electronic schedule and contact lists and have (modified) handwriting recognition capabilities, and support other productivity tools which have become popular. Voice-entry devices have found some utility where noncontinuous speech is supported by good screen design (see Chap. 5). The introduction of computer tablets with handwriting recognition show promise for use in specialized clinical applications. Most likely, clinicians will require a variety of devices—some that are application specific and some that vary with personal preference. The important design consideration is that, if possible, the design of the display and the nature of the input devices should not be so tied to the application that change and modification are difficult.

14.5 Forces That Will Shape the Future of Health Care Information Systems

As we have discussed throughout this chapter, the changing landscape of the health-care industry and the strategic and operational requirements of HCOs and IDNs have accelerated the acquisition and implementation of HCISs. The acquisition and implementation of **Electronic Medical Records** (**EMRs**) have been a particular focus, especially with the availability of federal stimulus funding through the provisions of the **Health Information Technology for Economic and Clinical Health** (**HITECH**) Act under the **American Recovery and Reinvestment Act of 2009** (**ARRA**). Although there are many obstacles to implementation and acceptance of smoothly functioning, fully integrated HCISs, few people today would debate the critical role that information technology plays in an HCO's success or in an IDN's efforts at clinical and operational management.

We have emphasized the dynamic nature of today's health care environment and the associated implications for HCISs. A host of new requirements loom that will challenge today's available solutions. We anticipate additional expectations and requirements associated with the changing organizational landscape, technological advances, and broader societal changes.

14.5.1 Changing Organizational Landscape

Although the concepts underlying HCOs and IDNs are no longer new, the underlying organizational forms and business strategies of these complex organizations continue to evolve. The success of individual HCOs varies widely. Some, serving target patient populations such as those with heart disease or cancer or age-defined groups such as children, have been relatively more successful financially that those attempting to serve patients across a wide range of illnesses or those attempting to combine diverse missions of clinical care, teaching and research. IDNs, on the other hand, have by and large failed to achieve the operational improvements and cost reductions they were designed to deliver. It is possible that entirely new forms of HCOs and IDNs will emerge in the coming years. Key to understanding the magnitude of the information systems challenge for IDNs in particular is recognizing the extraordinary pace of change—IDNs reorganize,

merge, uncouple, acquire, sell off, and strategically align services and organizational units in a matter of weeks. While information technology is itself changing with accelerating frequency, today's state-of-the-art systems (computer systems and people processes) typically require months or years to build and refine.

All too frequently, business deals are cut with insufficient regard to the cost and time required to create the supporting information infrastructure. For IDNs even in the best of circumstances, the cultural and organizational challenges of linking diverse users and care-delivery settings will tax their ability to change their information systems environments quickly enough. These issues will increase in acuity as operational budgets continue to shrink—today's HCOs and IDNs are spending significant portions of their capital budgets on information-systems investments. In turn, these new investments translate into increased annual operating costs (costs of regular system upgrades, maintenance, user support, and staffing). Still most health care organizations devote at most 3–4 % of their total revenues to their information systems operating budgets; in other information-intensive industries (e.g., financial services, air transportation), the percentage of operating budgets devoted to information technology investment can be three to four times higher.

14.5.2 Technological Changes Affecting Health Care Organizations

Future changes in technology are hard to predict. For example, although we have heard for over two decades that voice-to-text systems are 5 years away from practical use, with the introduction of controlled vocabularies in areas such as radiology and pathology, we are beginning to see commercial products that can "understand" dictated speech and represent it as text that can then be structured for further analysis. First, the emergence of increasingly powerful processor and memory chips, and the decreasing cost of storage media will continue to be a factor in future health-systems design—although the tsunami of data coming from genomic medicine sequencing and analysis may be a significant challenge (see Chaps. 2, 25, and 26). Second, the ever expanding availability of Internet access, the increasing integration of voice, video, and data, and the availability of ever smaller platforms like tablets and smart phones, will challenge HCOs and IDNs to have communications capacity not only within their traditional domain but also to an extended enterprise that may include patients' homes, schools, and workplaces. Third, the design of modern software based on the replicability of code, code standards such as **XML**, and frameworks such as Services Oriented Architecture (SOA) should eventually yield more flexible information technology systems.

One of the most significant technological challenges facing HCOs and IDNs today occurs because, while much of the health care delivered today is within the four walls of a physician's office or a hospital, as the population ages, patients may seek care from both primary and specialty practices, may have multiple hospital visits (and even visits to multiple hospitals) and may increasingly be monitored in their homes. Health care information technologies (and clinical systems in particular) have focused historically on what happens within a physician's office or within a hospital, and not across physicians' office nor between the physicians' office and the hospital nor in the home of the patient.

In general, EHR products on the market today started with a single purpose: to automate the workflow of clinicians within a particular organizational setting. Among other features, EHRs focus on making data from previous encounters or activities easier to access, and assuring that orders for tests and x-rays have the correct information, or that the next shift knows what went on previously. In spite of visible successes and failures for all manner of products, EHRs in general can facilitate the automation of a complex workflow—of automating intra-organizational clinical processes.

Architectures that focus on what happens *within* organizational boundaries do not easily facilitate access to data *across* organizational

boundaries. This is the challenge of **interoperability**. Recognizing that patients often receive care in a variety of organizational settings—hospitals, physicians offices, rehabilitation facilities, pharmacies, etc.—the challenge is to extend the internal workflow beyond the boundaries of individual organizations so that data is available across a continuum of care. Interoperability then is not so much about what happens *within* an organization (although there can be challenges here as well), but what happens *across* organizational boundaries.

The architectural requirements for automating *intra*-organizational clinical workflows are very different from the architectural requirements for facilitating *inter*-organizational interoperability. An *intra*-organizational architecture focuses on facilitating real time communications among providers, on optimizing the process of collecting data at the point of care, and on ensuring that clinical tasks are carried out in an appropriate sequence. An *inter*-organizational architecture needs to be designed to minimize the duplicate collection of data in different care settings, to facilitate quick searches of relevant data from a variety of (often external) sources, and to rank data in terms of relevance to a particular clinical question. Transitioning from *intra-* to *inter-organizational* data sharing is a significant technological challenge. While Health Information Exchanges (HIEs) and Health Record Banks (HRBs) are at the forefront of this transition (see Chap. 13), over time we can expect that the architectures of clinical systems that currently focus on what happens *within* an organization will need to transition to facilitate what happens *across* organizations.

Security and confidentiality concerns will likely increase as the emergence of a networked society profoundly changes our thinking about the nature of health care delivery. Health services are still primarily delivered locally—we seldom leave our local communities to receive health care except under the most dire circumstances. In the future, providers and even patients will have access to health care experts that are dispersed over state, national, and even international boundaries. Distributed health care capabilities will need to support the implementation of collaborative models that could include virtual house calls and routine **remote monitoring** via telemedicine linkages (see Chap. 18).

14.5.3 Societal Change

At the beginning of the twenty-first century, clinicians find themselves spending less time with each patient and more time with administrative and regulatory concerns. This decrease in clinician–patient contact has contributed to declining patient and provider satisfaction with care-delivery systems. At the same time, empowered health consumers interested in self-help and unconventional approaches have access to more health information than ever before. These factors are changing the interplay among physicians, care teams, patients, and external (regulatory and financial) forces. The changing model of care, coupled with changing economic incentives to deliver high quality care at lower cost, places a greater focus on wellness and preventative and lifelong care. Although we might agree that aligning economic incentives with wellness is a good thing, this alignment also implies a shift in responsibility from care givers to patients.

Like the health care environment, the technological context of our lives is also changing. The Internet has already dramatically changed our approaches to information access and system design. Concurrent with the development of new standards of information display and exchange is a push led by the entertainment industry (and others) to deliver broadband multimedia into our homes. Such connectivity has the potential to change care models more than any other factor we can imagine by bringing fast, interactive, and multimedia capabilities to the household level. Finally, vast amounts of information can now be stored efficiently on movable media such as **memory sticks**, which brings more flexibility as well as more risk, as such devices are both more convenient and more susceptible to being lost or misplaced. With the increase in the availability of consumer-oriented health information, including, for example, video segments that show the

appearance and sounds of normal and abnormal conditions or demonstrate common procedures for home care and health maintenance, we can expect even more changes in the traditional doctor/patient relationship.

With societal factors pushing our HCOs and IDNs to change, cost constraints looming larger, and the likely availability of extensive computing and communication capacity in the home, in the work place, and in the schools, HCOs and health providers are increasingly challenged to rethink the basic operating assumptions about how to deliver care. The traditional approach has been facility and physician centric—patients usually come to the hospital or to the physician's office at a time convenient for the hospital or the physician. The HCO and IDN of the twenty-first century may have to be truly "patient centric", operating within a health care delivery system without walls, where routine health management is conducted in nontraditional settings, such as homes and workplaces, using the power of telemedicine and consumer informatics.

Suggested Readings

Christensen, C., Grossman, J., & Hwang, J. (2009). *The innovator's prescription*. New York: McGraw-Hill. This book builds on the author's previous work on disruptive innovation with specific applications to the health care industry. Christensen uses terms such as "precision medicine" to describe the advent of more personalized approaches to medical diagnosis and treatment, and builds on his analysis of disruptive business models in other industries to analyze both the underlying problems and challenges of our health care delivery system.

Lee, T., & Mongan, J. (2009). *Chaos and organization in health care*. Cambridge, MA: The MIT Press. The authors describe the current health care situation as one simply of "chaos". Among the solutions they propose are increasing the use of electronic medical records and information technology in general for sharing knowledge.

Ong, K. (2011). *Medical informatics: an executive primer* (2nd ed.). Chicago: Health care and Management Information Systems Society. An excellent overview of the challenges facing information technology applications in hospitals, physicians' offices, and in the homes of patients. Also includes a discussion of recent federal legislation intended to stimulate the use of electronic medical records and the challenges of measuring how to determine whether such investments are in fact "meaningfully used".

Porter, M., & Teisberg, E. (2006). *Redefining health care: creating value-based competition on results*. Cambridge, MA: Harvard Business School Press. The authors begin with a very straightforward assumption, which is that "the way to transform health care is to realign competition with *value for patients*" (p. 4), and proceed with an exhaustive discussion of the historical failures at reforming the health care system, the challenges inherent in physician-provider organization relationships, and how the only likely solution set to the current high cost of health care is to focus our efforts on what brings value to the patients.

Questions for Discussion

1. Briefly explain the differences among an HCO's operational, planning, communications, and documentary requirements for information. Give two examples in each category. Choose one of these categories, and discuss similarities and differences in the environments of an integrated delivery network, a community-based ambulatory-care clinic, and a specialty-care physician's office. Describe the implied differences in these units' information requirements.
2. Describe three situations in which the separation of clinical and administrative information could lead to inadequate patient care, loss of revenue, or inappropriate administrative decisions. Identify and discuss the challenges and limitations of two methods for improving data integration.
3. Describe three situations in which lack of integration of information systems with clinicians' workflow can lead to inadequate patient care, reduced physician productivity, or poor patient satisfaction with an HCO's services. Identify and discuss the challenges and limitations of two methods for improving process integration.
4. Describe the trade-off between functionality and integration. Discuss three

strategies currently used by HCOs to minimize this tradeoff.

5. Assume that you are the chief information officer of multi-facility HCO. You have just been charged with planning a new clinical HCIS to support a large tertiary care medical center, two smaller community hospitals, a nursing home, and a 40-physician group practice. Each organization currently operates its own set of integrated and standalone technologies and applications. What technical and organizational factors must you consider? What are the three largest challenges you will face over the next 24 months?
6. How do you think the implementation of clinical HCISs will affect the quality of relationships between patients and providers? Discuss at least three potential positive and three potential negative effects. What steps would you take to maximize the positive value of these systems?