12 Electronic Health Record Systems

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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.

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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.

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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

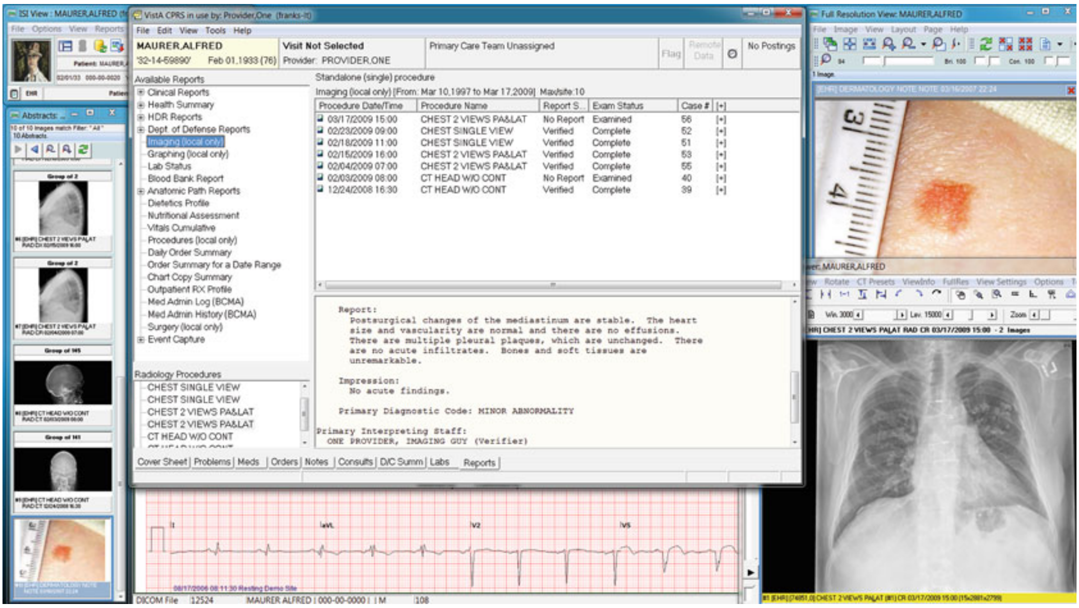


Fig. 12.1 A screenshot of the combined WorldVistA Computer Based Patient Record System (CPRS) and ISI Imaging system. These systems are derived from the Department of Veterans Affairs VistA and VistA Imaging systems (http://www.va.gov/vista_monograph/). The image illustrates the opportunity to present 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).

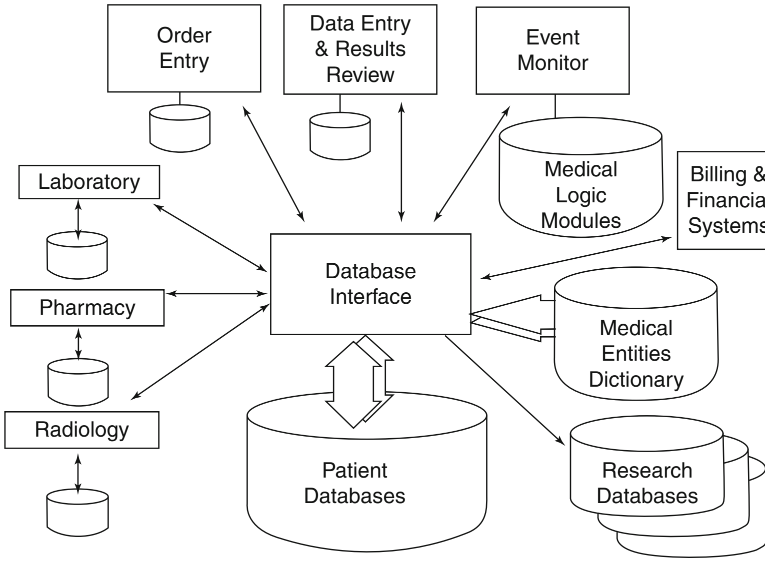


Fig. 12.2 A block diagram of multiple-source-data systems that contribute patient data, which ultimately reside in a computerized patient record (CPR). The database interface, commonly called an interface engine, may perform a number of functions. It may simply be a router of information to the central 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).

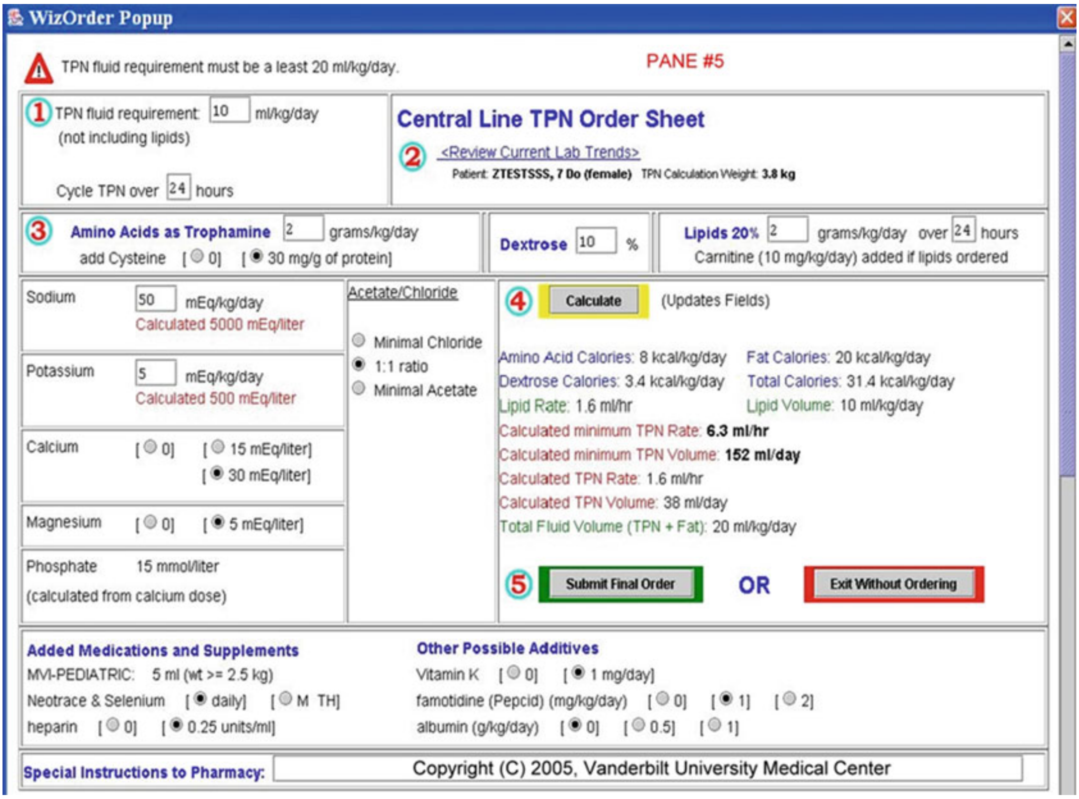


Fig. 12.3 Neonatal Intensive Care Unit (NICU) Total Parenteral Nutrition (TPN) Advisor provides complex interactive advice and performs various calculations in response to the provider's prescribed goal for amount of fluid, calories, nutrition, and special additives (Source: Miller et al. (2005b). Elsevier 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

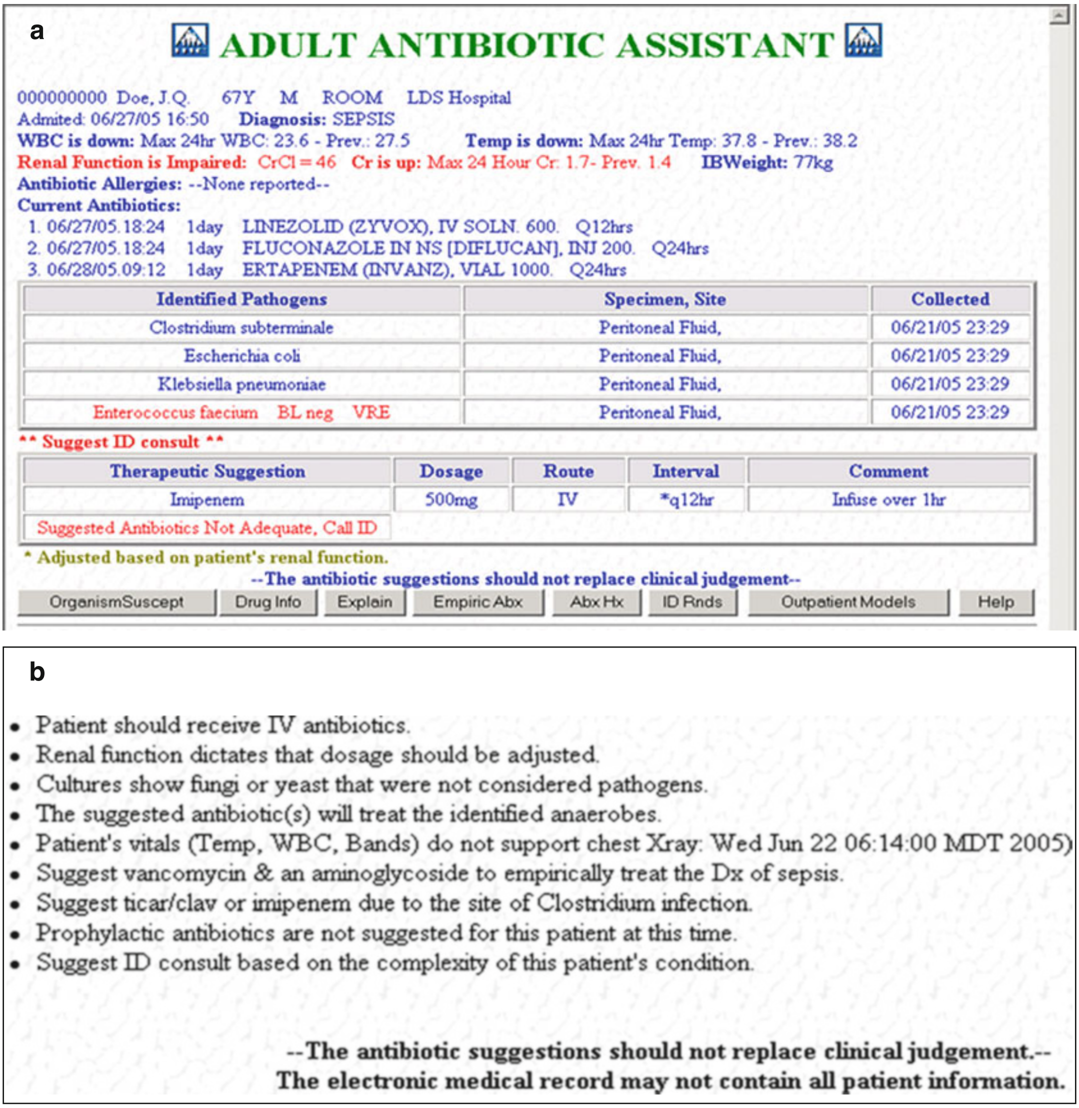


Fig. 12.4 Example of the main screen (**a**) from the Intermountain Health Care Antibiotic Assistant program. The program displays evidence of an infection-relevant patient data (e.g., kidney function, temperature), recommendations for antibiotics based on the culture results, and (**b**) disclaimers (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).

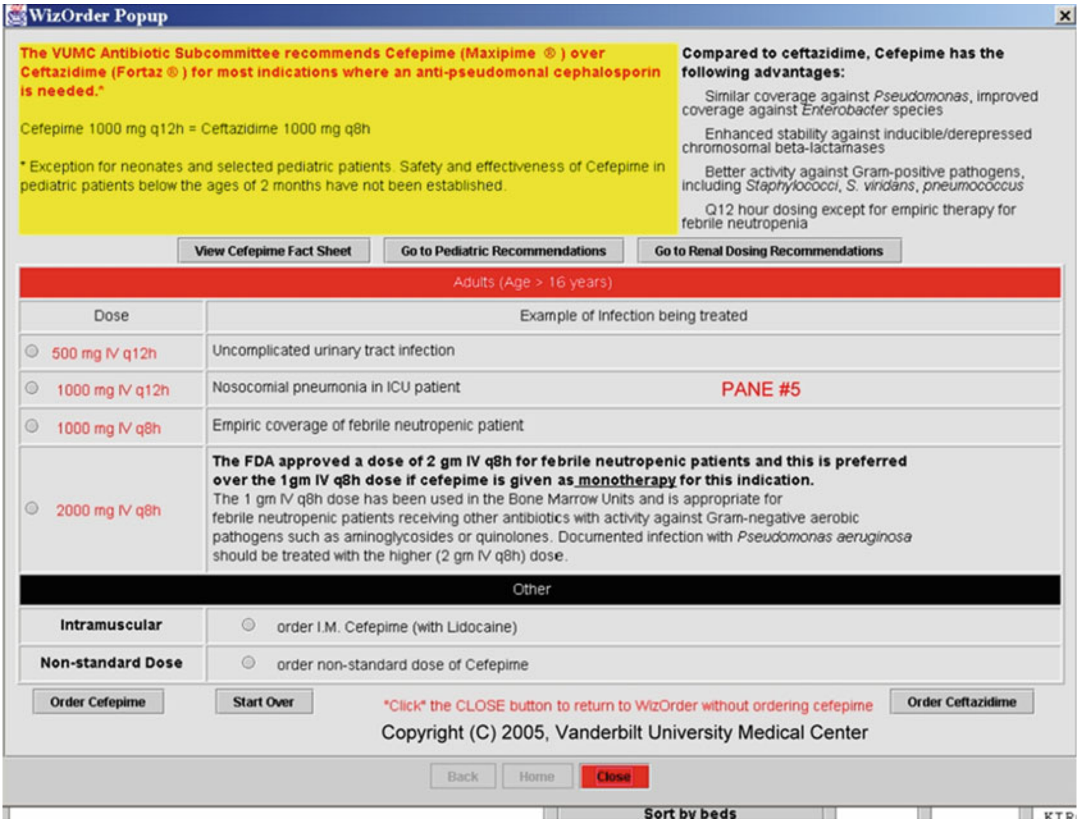


Fig. 12.5 User ordered an antibiotic for which the Vanderbilt's inpatient "WizOrder" order entry (CPOE) system, based on their Pharmaceuticals and Therapeutics (PandT) Committee input, recommended a substitution. This educational advisor guides clinician through ordering an alternative antibiotic. Links 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).

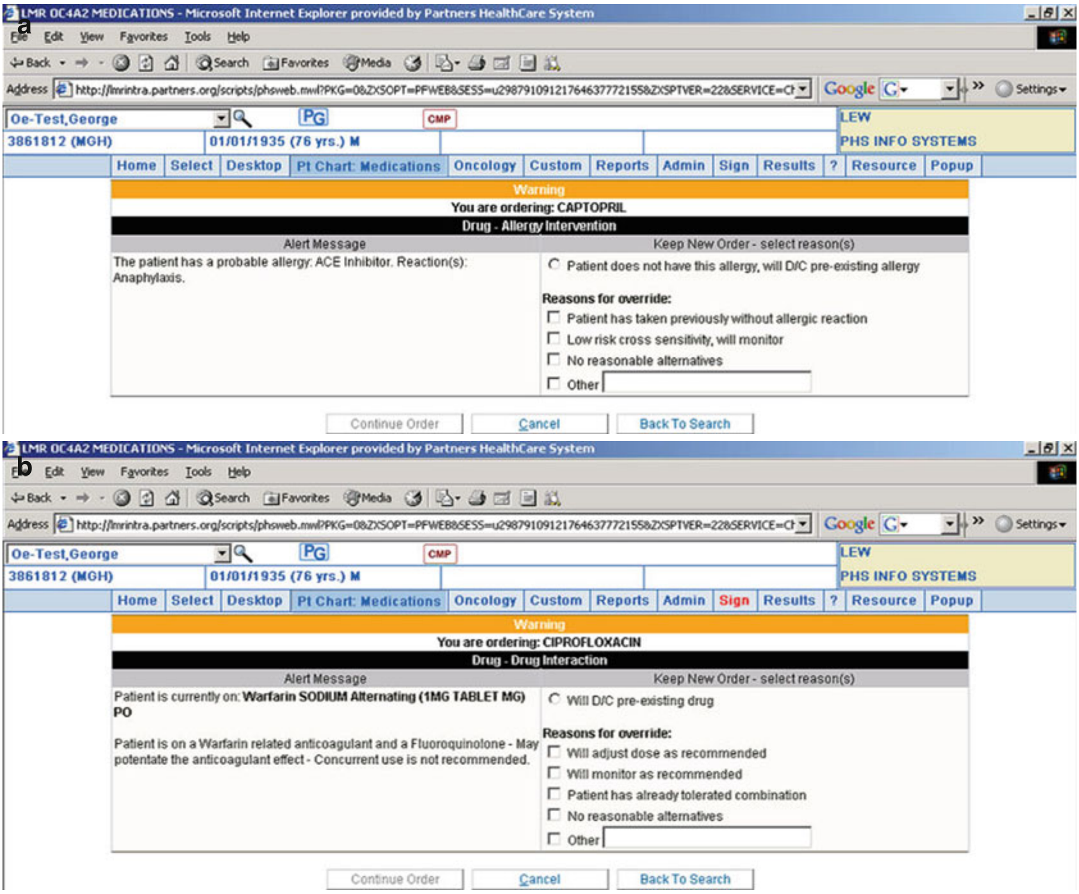


Fig. 12.6 Drug-alert display screens from Partners outpatient medical record application (Longitudinal Medical Record, LMR). The screens show (**a**) a drug-allergy alert for captopril, and (**b**) a drug-drug interaction between ciprofloxacin and warfarin (Source: Courtesy of Partners Health Care System,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

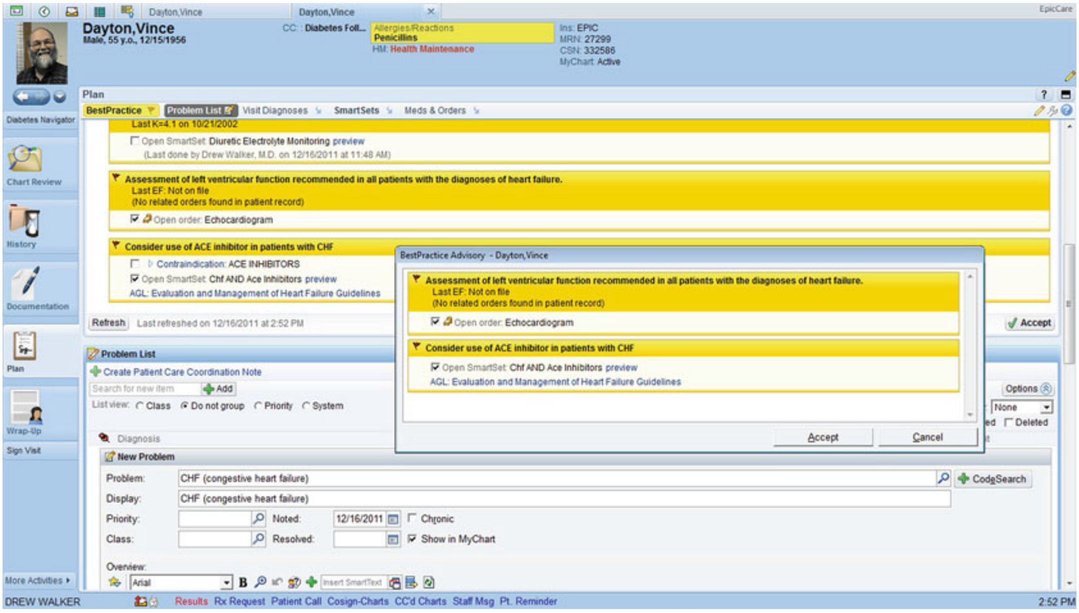


Fig. 12.7 Example of clinical decision support alerts to order an echocardiogram and to start an ACE inhibitor in a patient with diagnosed congestive heart failure (Source: Courtesy of Epic Systems, Madison, WI)

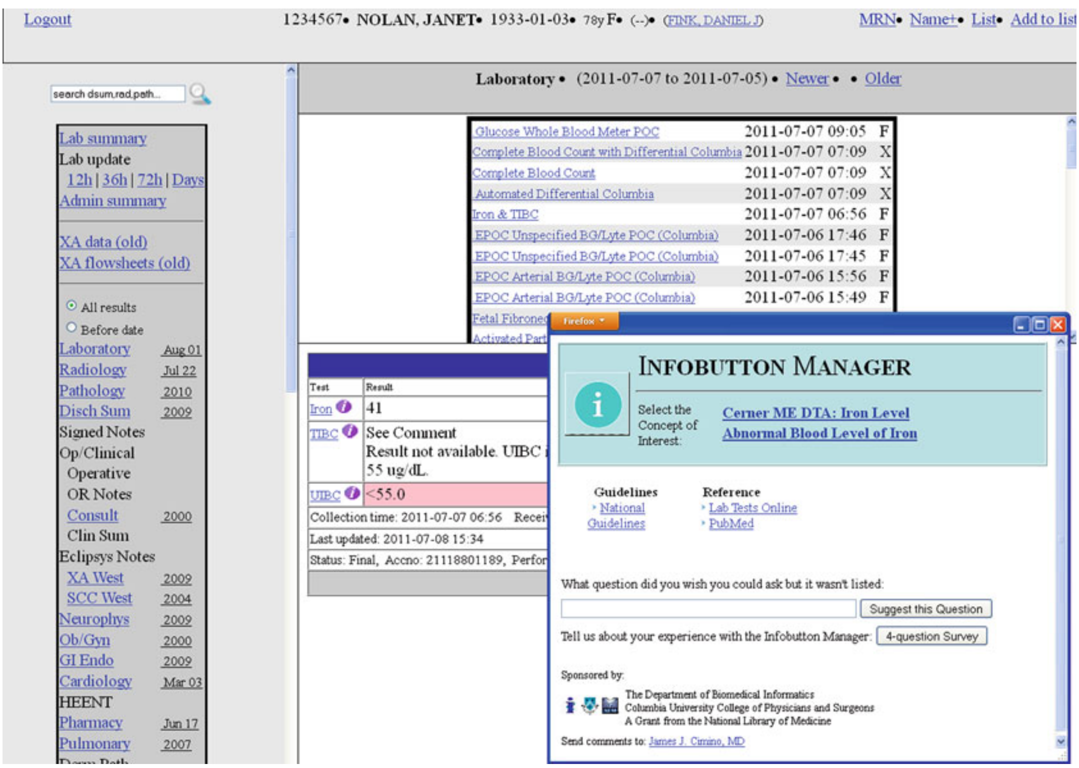


Fig. 12.8 This figure shows the use of Columbia University Medical Center's info-buttons during results review. Clicking on the info-button adjacent to the Iron result generates a window (image) with a menu of questions. When the user clicks on one of the questions, the info button delivers the answers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

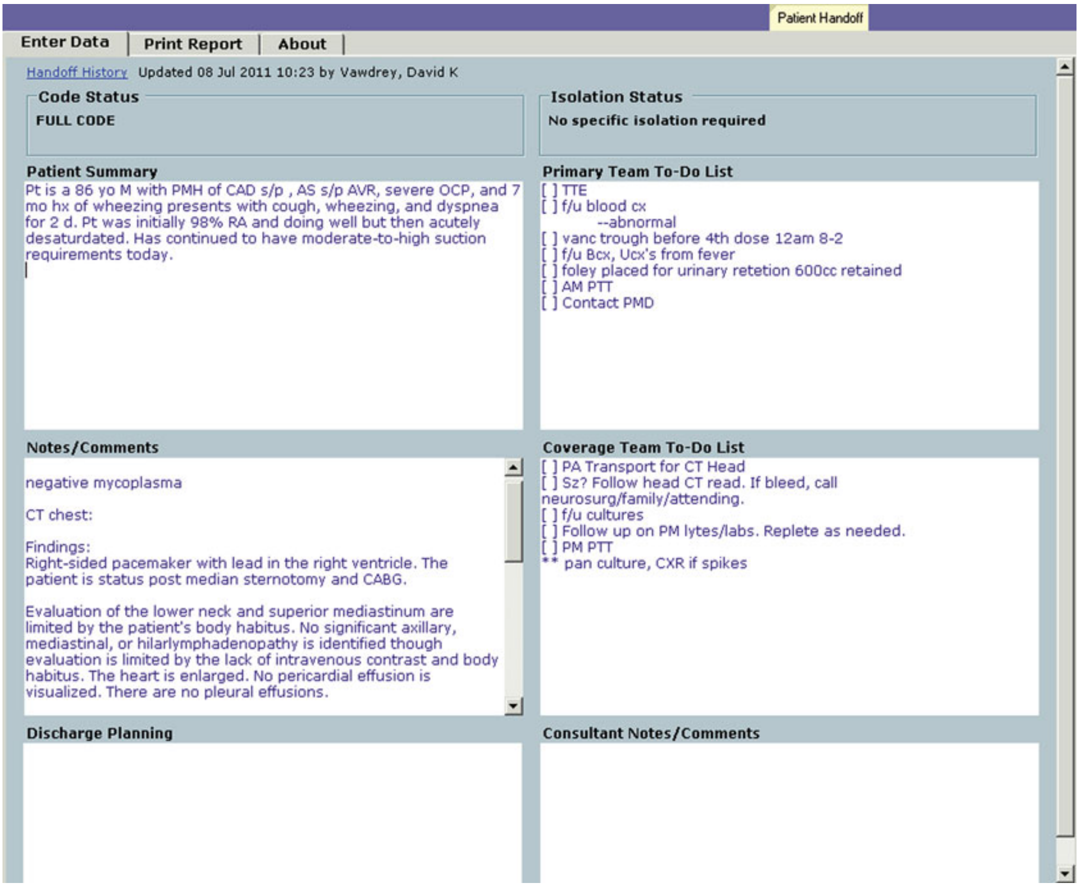


Fig. 12.9 Patient handoff report—a user-customizable hard copy report with automatic inclusion of patient allergies, active medications, 24-h vital signs, recent common laboratory test results, isolation requirements, code status, and other EHR data. This system was developed by a customer within a vendor 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 <u>all</u> 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. Uncooperative / Unable to Screen: ☐ Vision ☐ Hearing ☐ BP

Weight: 14 . 2 kg. Vision Left: 20/

HC: . cm. Vision Right: 20/ Pulse Ox: %

BP: / Left Ear @ 25db: P F ☐ ☐ Right Ear @ 25db: P F ☐ ☐

Temp: . deg. F

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

Pulse: /min RR:

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

Is Jenny having pain today?

Does Jenny take prescription or over-the-counter medicine, herbal medicine or vitamins, or use an inhaler or medicated creams or lotions?

Does Jenny say six or more words other than 'Mama', 'Dada' and names of family members or pets?

Has your partner kicked, hit, or slapped you?

Does Jenny always wear a helmet when riding her bike or tricycle?

Does Jenny usually watch TV or computer more than 2 hours a day?

Do you know what to do if Jenny is choking?

Has your partner or another adult threatened or hurt your children?

Has Jenny seen a dentist this year?

Are any firearms or guns kept in Jenny's home?

Y N

Please fill out the attached form about Jenny's development.

Can Jenny take off any of her clothes, such as pajamas (tops or bottoms) or pants? Do not count diapers, hats, socks, or shoes.

Do you feel safe in your home?

Jenny has sickle cell disease (HbSS). Is she taking antibiotics twice a day, every day?

Does Jenny have a TV in her room?

Does anyone in Jenny's home smoke?

Has Jenny ever been around water when an adult has not been within an arm's length?

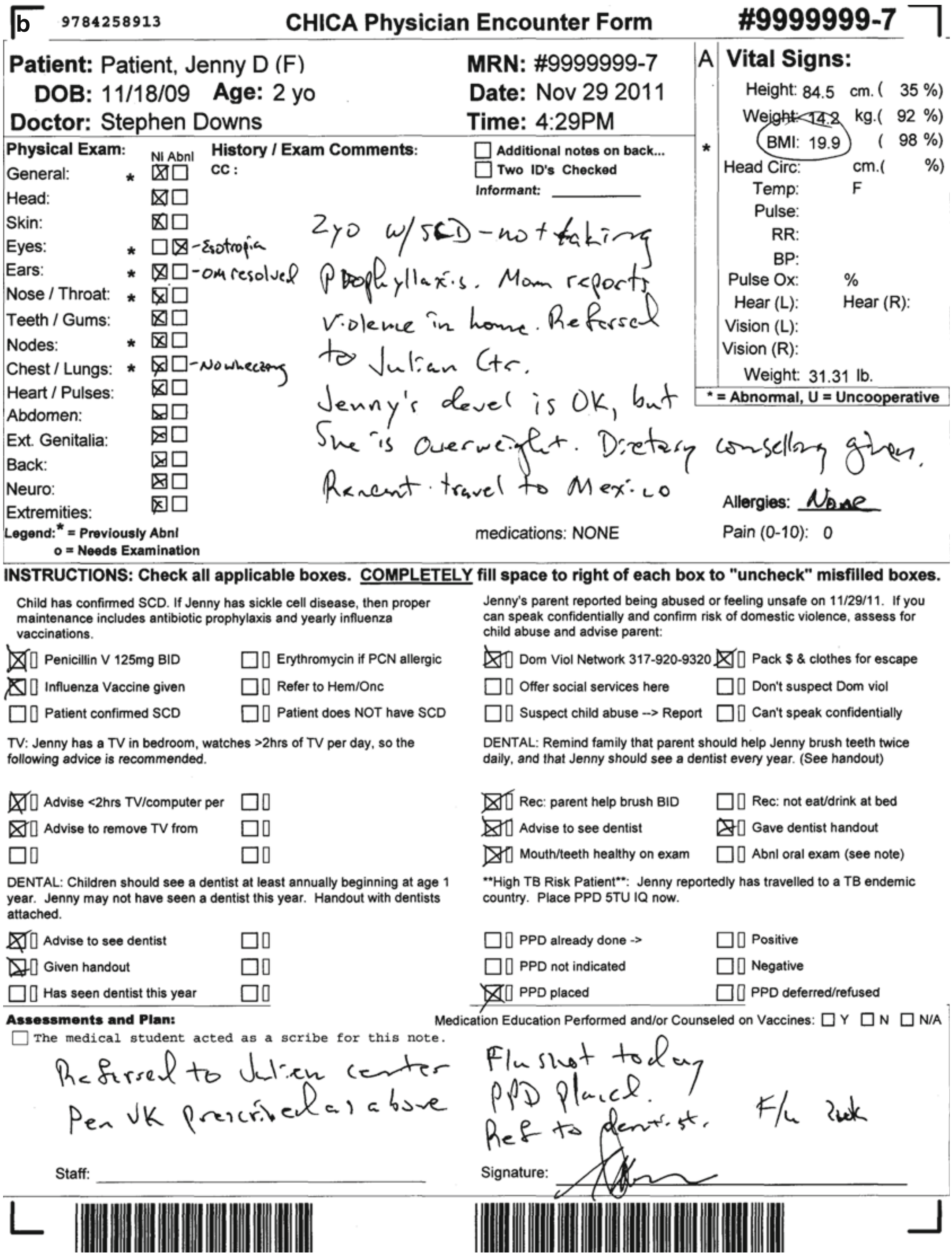
Does Jenny ever use a bottle?

Is Jenny on the WIC program?

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

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

Physical Exam: Nl Abnl
General: * ☒ ☐
Head: ☒ ☐
Skin: ☒ ☐
Eyes: * ☐ ☒ - Esotropia
Ears: * ☒ ☐ - OM resolved
Nose / Throat: * ☒ ☐
Teeth / Gums: ☒ ☐
Nodes: * ☒ ☐
Chest / Lungs: * ☒ ☐ - No wheezing
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 prophyllaxis. Mom reports violence in home. Referred to Julian Ctr.
Jenny's level is OK, but she is overweight. Dietary counselling given.
Recent travel to Mexico

medications: NONE
Allergies: 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: Medication Education Performed and/or Counseled on Vaccines: ☐ Y ☐ N ☐ N/A
☐ The medical student acted as a scribe for this note.

Referred to Julian center
Pen VK prescribed as above

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

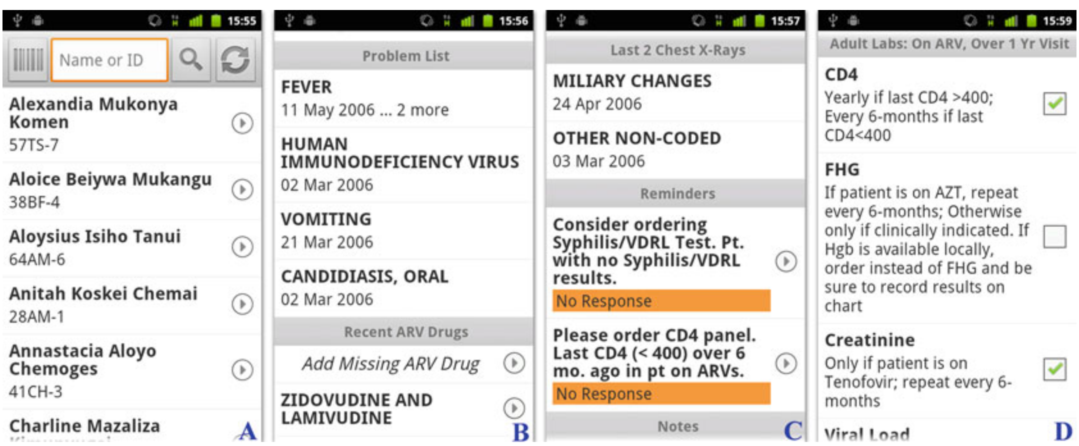


Fig. 12.11 ODK Clinic is a mobile clinical decision support system that helps providers make faster and better decisions about care. Providers equipped with ODK Clinic on a mobile phone or tablet can (**a**) access a list of patients (**b**) and (**c**) download patient summaries that include data from 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 preexisting 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).

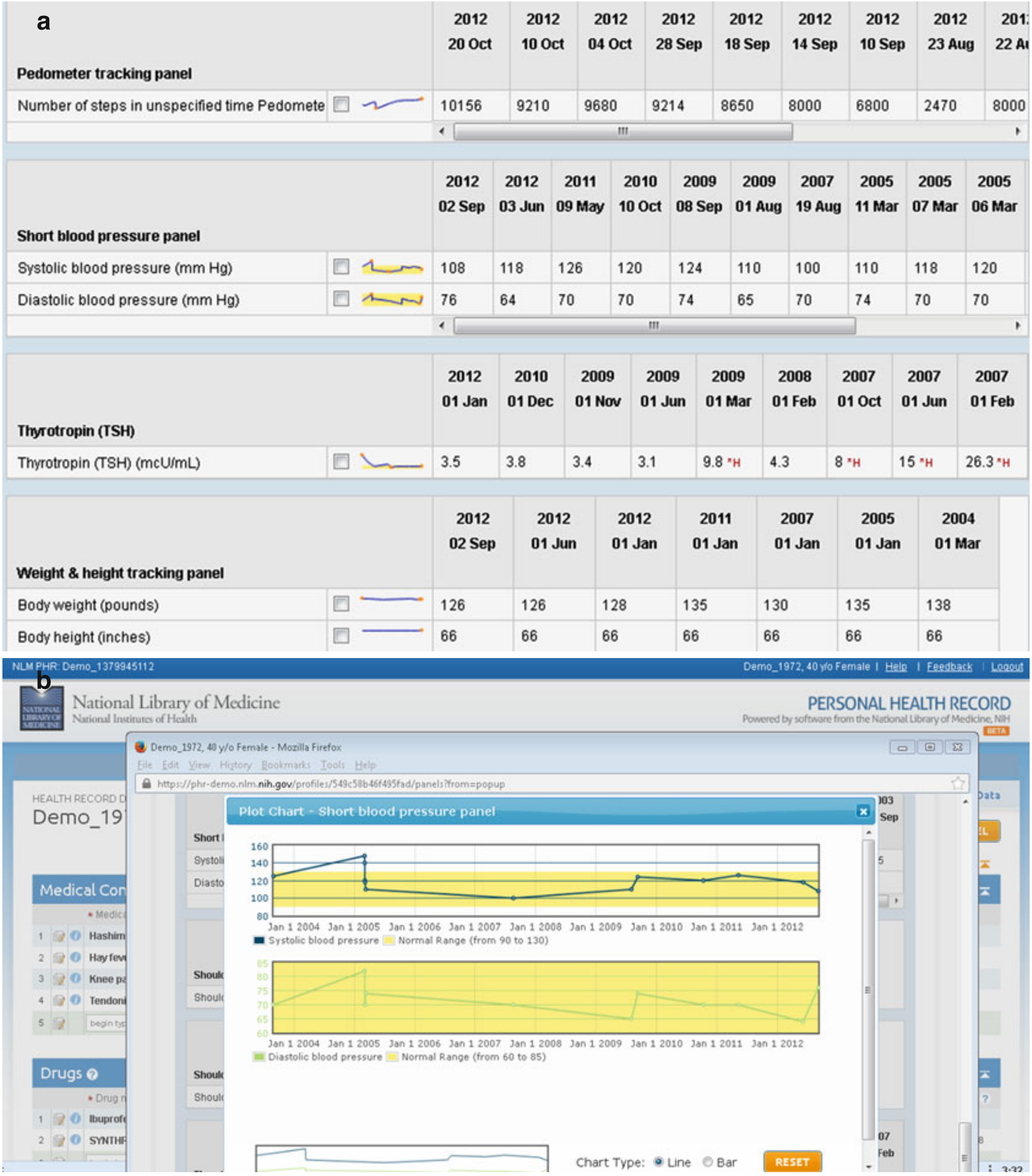


Fig. 12.12 The National Library of Medicine Personal Health Record (PHR) flow sheet (**a**) allows the consumer to track test, treatments and symptoms over time. Clicking on a sparklines graph in the flow sheet table opens a larger plot chart view (**b**) consumers can click on multiple sparklines to 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

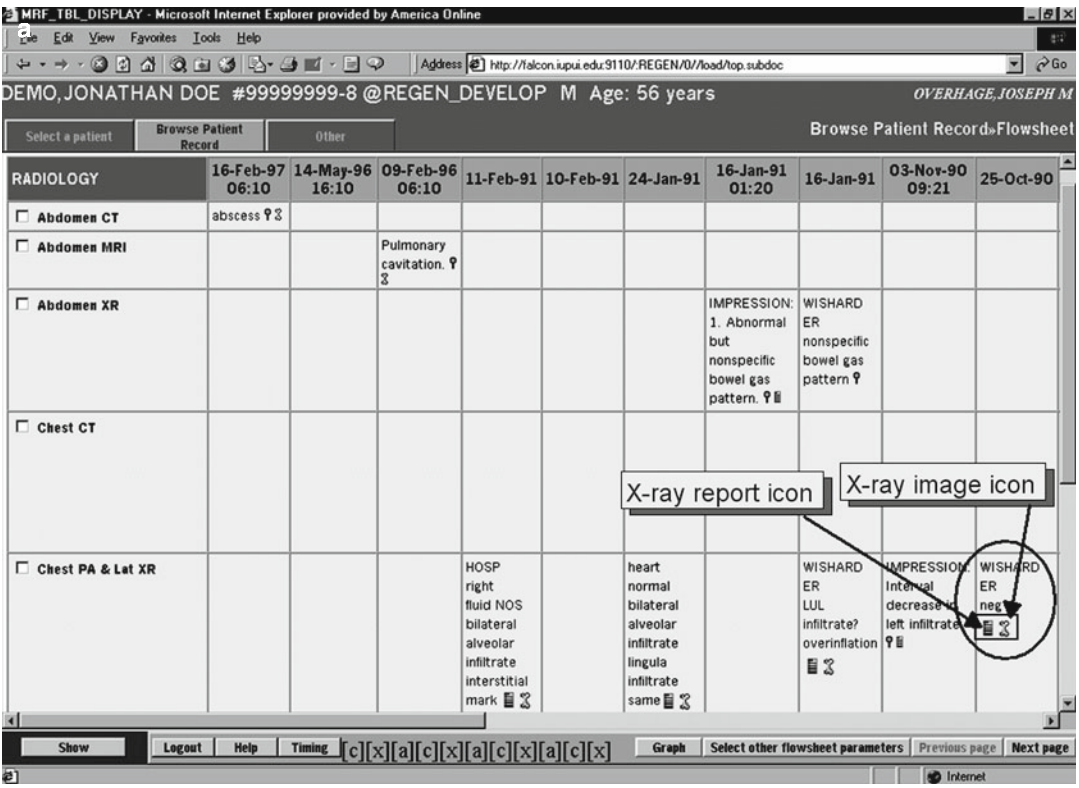


Fig. 12.13 Web resources. (**a**) Web-browser flow sheet of radiology reports. The rows all report one kind of study, and the columns report one date. Each cell shows the impression part of the radiology report as a quick summary of the content of that report. The cells include two icons. Clicking on 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)

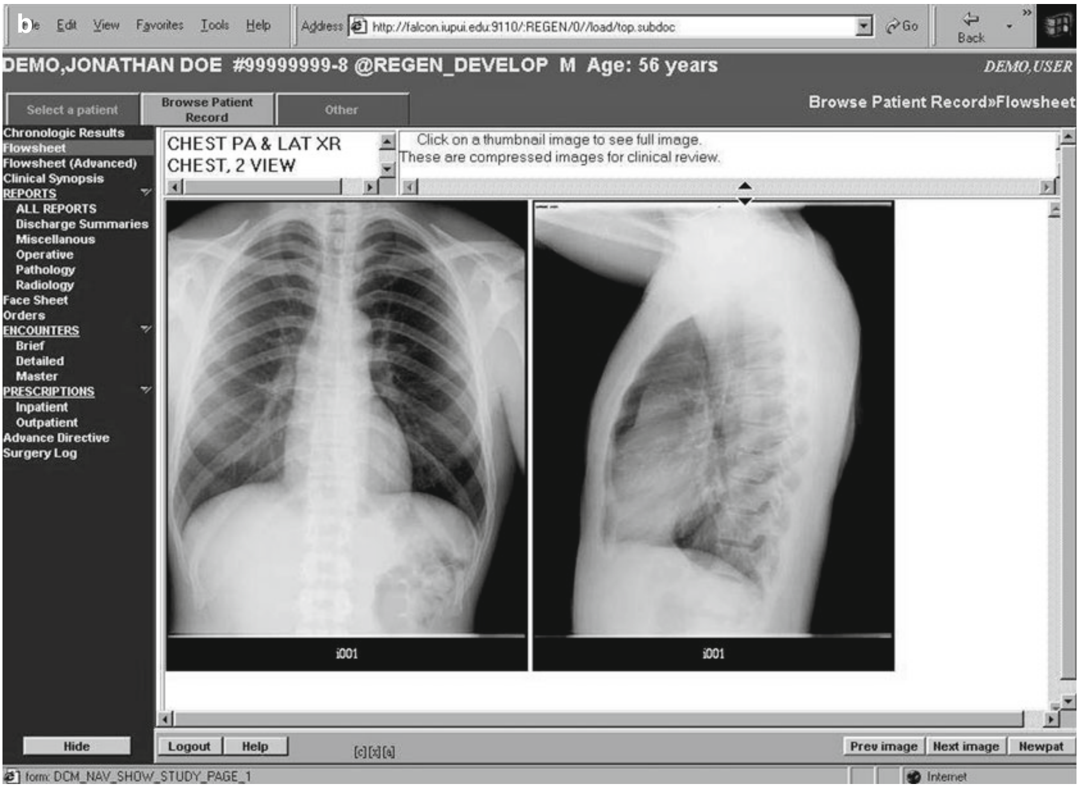


Fig. 12.13 (continued)

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.

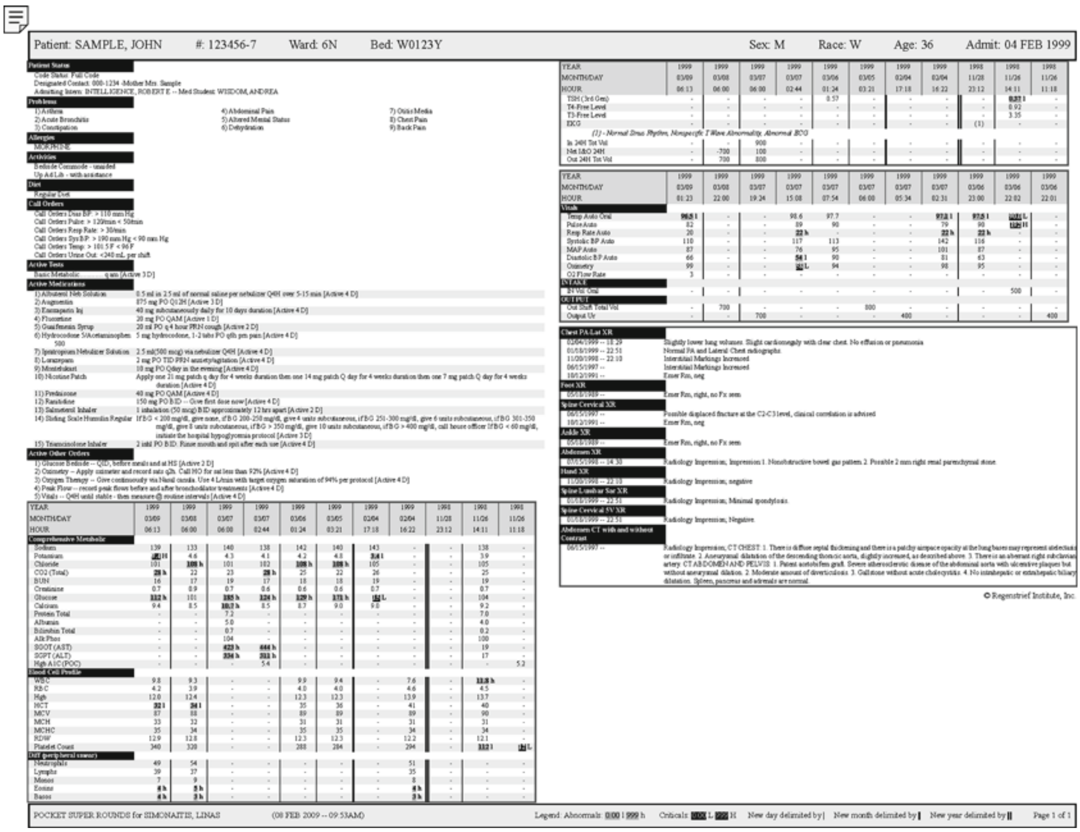


Fig. 12.14 The Pocket rounds report—so called because when folded from top to bottom, it fits in the clinician's white coat pocket as a booklet. It is a dense report (12 lines per inch, 36 characters per inch), printed in landscape mode on one 8 1/2×11 in. page), and includes the all active orders (including 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.

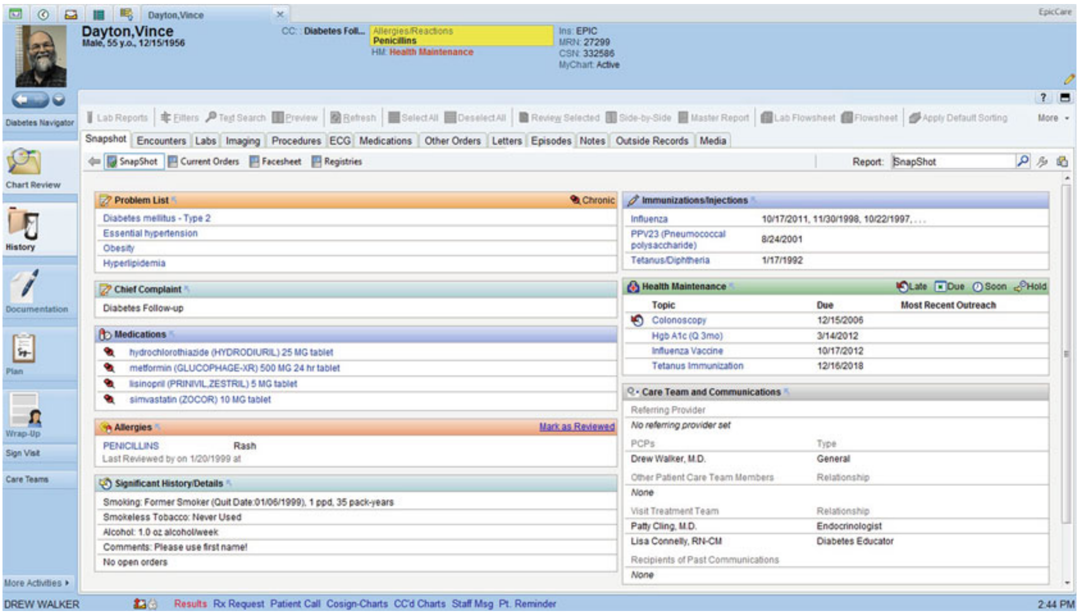


Fig. 12.15 Summary record. The patient's active medical problems, current medications, and drug allergies are among the core data that physicians must keep in mind when making any decision on patient care. This one-page screen provides an instant display of core clinical data elements as well as reminders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

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[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?