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9 Computer-Based Patient-Record Systems

PAUL C. TANG AND CLEMENT J. MCDONALD

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

- What is the definition of a computer-based patient record (CPR)?
- How does a CPR differ from the paper record?
- What are the functional components of a CPR?
- What are the benefits of a CPR?
- What are the impediments to development and use of a CPR?

9.1 What Is a Computer-Based Patient Record?

The preceding chapters introduced the conceptual basis for the field of medical 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** or **medical record**. The patient record is an amalgam of all the data acquired and created during a patient's course through the healthcare system. The use of medical data was covered extensively in Chapter 2. We also discussed the limitations of the paper record in serving the many users of patient information. In this chapter, we examine the definition and use of computer-based patient-record systems, discuss their potential benefits and costs, and describe the remaining challenges to address in their dissemination.

9.1.1 Purposes 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. Yet, observational studies of physicians' use of the paper-based record find that logistical, organizational, and other practical limitations reduce the effectiveness of traditional records for storing and organizing an ever-increasing number of diverse data. A computer-based patient record is designed to overcome many of these limitations, as well as to provide additional benefits that cannot be attained by a static view of events.

A **computer-based patient record** (CPR) is a repository of electronically maintained information about an individual's lifetime health status and health care, stored such that it can serve the multiple legitimate users of the record. Traditionally, the patient record was a record of care provided when a patient is ill. Managed care (discussed in Chapter 19) encourages healthcare providers to focus on the continuum of health and health care from wellness to illness and recovery. Consequently, the record must integrate elements regarding a patient's health and illness acquired by multiple providers across diverse settings. In addition, the data should be stored such that different views of those data can be presented to serve the many uses described in Chapter 2.

A **computer-based patient-record system** adds information-management tools to provide clinical reminders and alerts, linkages with knowledge sources for health-care decision support, and analysis of aggregate data. To use a paper-based patient record, the reader must manipulate data either mentally or on paper to glean important clinical information. In contrast, a CPR system provides computer-based tools to help the reader organize, interpret, and react to data. Examples of tools provided in current CPR systems are discussed in Section 9.3.

9.1.2 Ways in Which a Computer-Based Patient Record Differs from a Paper-Based Record

In contrast to a traditional patient record, whose functionality is tethered by the static nature of paper—a single copy of the data stored in a single format for data entry and retrieval—a CPR is flexible and adaptable. Data may be entered in a format that simplifies the input process (which includes electronic interfaces to other computers where patient data are stored) and displayed in different formats suitable for their interpretation. Data can be used to guide care for a single patient or in aggregate form to help administrators develop policies for a population. Hence, when considering the functions of a CPR, we do not confine discussion to the uses of a single, serial recording of provider–patient encounters. A CPR system extends the usefulness of patient data by applying information-management tools to the data.

Inaccessibility is a common drawback of paper records. In large organizations, the traditional record may be unavailable to others for days while the clinician finishes documentation of an encounter. For example, paper records are often sequestered in a medical records department until the discharge summary is completed and every document is signed. During this time, special permission and extra effort are required to locate and retrieve the record. Individual physicians often borrow records for their convenience, with the same effect. With computer-stored records, all authorized personnel can access patient data immediately as the need arises. Remote access to CPRs also is possible. When the data are stored on a secure network, authorized clinicians with a need to know can access them from the office, home, or emergency room, to make timely informed decisions.

Documentation in a CPR is usually more legible because it is recorded as printed text rather than as hand writing, and it is better organized because structure is imposed on input. The computer can even improve completeness and quality by automatically applying validity checks on data as they are entered. For example, numerical results can be checked against reference ranges. Typographical errors can be detected if a datum fails a reference range check. Moreover, an interactive system can prompt the user for additional information. In this case, the data repository not only stores data but also enhances their completeness.

Data entered into a computer can be reused. For example, a physician could reuse her clinic visit note in the letter to the referring physician and the admission note. Reusability of data is one way that a CPR increases efficiency of the provider's workflow. Reuse of data also increases the quality of data. The more users and uses that depend on a data element, the more likely that it will be reviewed and be kept up to date.

The degree to which a particular CPR demonstrates these benefits depends on several factors:

1. *Comprehensiveness of information.* Does the CPR contain information about health as well as illness? Does it include information from all 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?
2. *Duration of use and retention of data.* A record that has accumulated patient data over 5 years will be more valuable than is one that contains records of only the visits made during 1 month.
3. *Degree of structure of data.* Medical data that are stored simply as narrative text entries will be more legible and accessible than are similar entries in a paper medical record. Uncoded information, however, is not standardized (see Chapter 6), and inconsistent use of medical terminology limits the ability to search for data. Use of a controlled, predefined vocabulary facilitates automated aggregation and summarization of data provided by different physicians or by the same physician at different times. Coded information is also required for computer-supported decision making and clinical research.
4. *Ubiquity of access.* A system that is accessible from a few sites will be less valuable than one accessible from any computer by an authorized user (see Chapter 4).

A computer-stored medical record system has disadvantages. It requires a larger initial investment than its paper counterpart due to hardware, software, training, and support costs. Key personnel may have to spend time away from their practice to learn how to use the system and to redesign their workflow to use the system efficiently. Physicians will also have to spend time learning how to use the system. Their workflow and their interactions with their patients may change. Converting from a paper-based medical-record system to a CPR involves substantial time, resources, determination, and leadership. The human and organizational factors often dominate the technical challenges.

Another risk associated with computer-based systems is the potential for subtle as well as catastrophic failures. If the computer system fails, stored information may be unavailable for an indeterminate time. Paper records fail one chart at a time. On the other hand, if we consider that a given chart may be unavailable up to 30 percent of the time, the paper-based system may be considered to be down 30 percent of the time for any given patient. Organizations can take steps to decrease the risk of CPR outages by providing redundancy for everything from computers and disk drives to networks and personal workstations. As a last resort, temporary paper records can act as a backup system until the computer system becomes available again.

Physicians record large amounts of clinical information in their history, physical examination, and progress notes. Capture of this information directly from the physician format is a major goal of medical informatics because it provides the most timely, accurate, and useful content. However, the goal is elusive. The time cost of physician input can be high, and many physicians initially resist the use of computers to enter data. Although new input devices are introduced or improved each year (e.g., pen-based entry, speech input), problems with convenience, portability, cost, and accuracy have made it difficult for these devices to compete with pen and paper. Dictation remains an option for data entry, but the turnaround time required for the dictation to be transcribed and for someone to review, correct, sign, and file the transcribed document creates delays. The lack of encoding further reduces the benefits of using a CPR.

To avoid the problem of data entry by physicians, some institutions have resorted to scanning physicians' notes into the computer (Teich, 1997). Scanned documents do solve the availability problems of the paper chart because they can be retrieved and viewed from any computer device. A typical scanned document occupies 50,000 bytes, however, so the downloading time can be slow, and there is no option for searching or analyzing the content of a scanned document without an abstraction step.

Although it takes time to learn how to use the system and to change workflows, we expect the long-term benefits of a CPR to compensate for the short-term costs. Thus far, however, there are few empirical data from large-scale evaluations of CPR systems. Hence, a strong belief in the anticipated benefits of CPR systems by senior leadership is required to embark on the process of migrating from paper to electronic records.

9.2 Historical Perspective

The historical development of the medical record parallels the development of science in clinical care. The development of automated systems for dealing with healthcare data parallels the need for data to comply with reimbursement requirements. Early healthcare systems focused on inpatient-charge capture to meet billing requirements in a fee-for-service environment. Contemporary systems need to capture clinical information in a managed-care environment focusing on clinical outcomes in ambulatory care.

9.2.1 Early Hospital Focus

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, it also encouraged physicians to keep a patient-oriented medical record. The contents of medical records in hospitals became the object of scrutiny in the 1940s, when hospital-accrediting bodies began to insist on the availability of accurate, well-organized medical records as a condition for accreditation. Since then, these organizations also have required that hospitals abstract certain information from the medical record and submit that information to national data centers. Such discharge abstracts contain (1) demographic information, (2) admission and discharge diagnoses, (3) length of stay, and (4) major procedures performed. The national centers produce statistical summaries of these case abstracts; an individual hospital can then compare its own statistical profile with that of similar institutions.

In the late 1960s, computer-based hospital information systems (HISs) began to emerge (see also Chapter 10). These systems were intended primarily for communication. They collected orders from nursing stations, routed the orders to various parts of the hospital, and identified all chargeable services. They also gave clinicians electronic access to results of laboratory tests and other diagnostic procedures. Although they contained some clinical information (e.g., test results, drug orders), their major purpose was to capture charges rather than to assist with clinical care. Many of the early HISs stored and presented much of their information as text, which is difficult to analyze. Moreover, these early systems rarely retained the content for more than a few days after a patient's discharge.

The introduction of the **problem-oriented medical record** (POMR) by Lawrence Weed (1969) influenced medical thinking about both manual and automated medical records. Weed was among the first to recognize the importance of an internal structure of a medical record, whether stored on paper or in a computer. He suggested that the primary organization of the medical record should be by the medical problem; all diagnostic and therapeutic plans should be linked to a specific problem.

Morris Collen (1983) was an early pioneer in the use of hospital-based systems to store and present laboratory-test results as part of preventive care. Use of computers to screen for early warning signs of illness was a basic tenet of health-maintenance organizations (HMOs). Other early university hospital-based systems provided feedback to physicians that affected clinical decisions and ultimately patient outcomes. The HELP system (Pryor, 1988) at LDS Hospital and the CCC system at Beth Israel Deaconess Medical Center (Bleich et al., 1985) continue to add more clinical data and decision-support functionality.

9.2.2 Influence of Managed Care and the Integrated Delivery System

Until recently, the ambulatory-care record has received less attention from the commercial vendors than the hospital record because of differences in financing and regulatory requirements. The status of ambulatory care records was reviewed in a 1982 report (Kuhn et al., 1984). Under the influence of managed care (described in detail in Chapter 19), the reimbursement model has shifted from a **fee-for-service model** (payers pay providers for all services the provider deemed necessary) toward a payment scheme where providers are paid a **fixed fee** for a specific service (payers pay a fixed amount for services approved by the payer). In some regions of the country, health-care–financing models are progressing toward a **capitated system** where providers are given a fixed fee to take care of all the health-care needs of a population of patients. In such managed-care environments, providers are motivated to reduce the cost of care by keeping their population of clients healthy and out of hospitals. Information-management tools that facilitate effective management of patients outside of the hospital setting help providers to achieve these goals. The emphasis on ambulatory care brought new attention to the ambulatory care record.

Thirty years ago, a single family physician provided almost all of an individual's medical care. Today, however, responsibility for ambulatory care is shifting to teams of health-care professionals in outpatient clinics and HMOs (see Chapter 19). Ambulatory care records may contain lengthy notes written by many different health-care providers, large numbers of laboratory-test results, and a diverse set of other data elements, such as X-ray–examination and pathology reports and hospital-discharge summaries. Accordingly, the need for information tools in ambulatory practice has increased. Among the early systems that focused on ambulatory care, COSTAR (Barnett, 1984), the Regenstrief Medical Record System (RMRS) (McDonald et al., 1992), STOR (Whiting-O'Keefe et al., 1985), and TMR (Stead & Hammond, 1988) are still available today.

9.3 Functional Components of a Computer-Based Patient-Record System

As we explain in Section 9.1.2, a CPR is not simply an electronic version of the paper record. When the record is part of a comprehensive CPR system, there are linkages and tools available to facilitate communication and decision-making. In

Sections 9.3.1 to 9.3.5, we summarize components of a comprehensive CPR system and illustrate functionality with examples from systems currently in use. The five functional components are:

- Integrated view of patient data
- Clinical decision support
- Clinician order entry
- Access to knowledge resources
- Integrated communication support

9.3.1 Integrated View of Patient Data

Clearly, providing integrated access to all patient data is a primary purpose of a CPR. Although this task may seem relatively simple, the growing volume of data for a patient from different sources (e.g., clinical laboratories, radiology departments, free-standing magnetic resonance imaging (MRI) centers, pharmacy outlets, home health agencies) make it difficult. For example, at present in the United States, no national patient identifier (similar to a social security number) exists for linking patient data obtained from many sites (patient indexes to link disparate patient identifiers are discussed in Chapter 10). Because different patient-data source systems use different identifiers, data-content terminologies, and data formats, most CPRs use **interface engines** to translate data content and formats from the sending system to ones that are acceptable to the receiving system. Although clinical data can be delivered to CPRs via **Health Level 7** (HL7), a relatively mature message standard (see Chapter 6), differences among implementations of HL7 must be resolved by interface engines. Figure 9.1 shows an example architecture to integrate data from multiple source systems. The database interface depicted not only provides message-handling capability but should also map the terminology of the sending system to a common vocabulary. Each receiving system that needs information about patients registers that interest with the interface engine to be sure that it receives appropriate updates (e.g., patient demographics). The interface engine often provides a technical and translation buffer between systems manufactured by different vendors. In this way, organizations can mix different vendors' products and still achieve the goal of integrated access to patient data for the clinician.

The idiosyncratic, local terminologies used to identify clinical variables and their values in many source systems represent a major barrier to integration of medical-record data by CPRs. Code systems such as LOINC (Forrey et al., 1996) and SNOMED (Rothwell & Côté, 1996), discussed in Chapter 6, help overcome these barriers.

Clinicians need more than just integrated access to patient data; they also need a specific **view** of patient data. Presenting an appropriate view of data for clinicians depends on an understanding of the context of the patient and of the clinician's data-analysis task. An example of a useful summary view of patient data

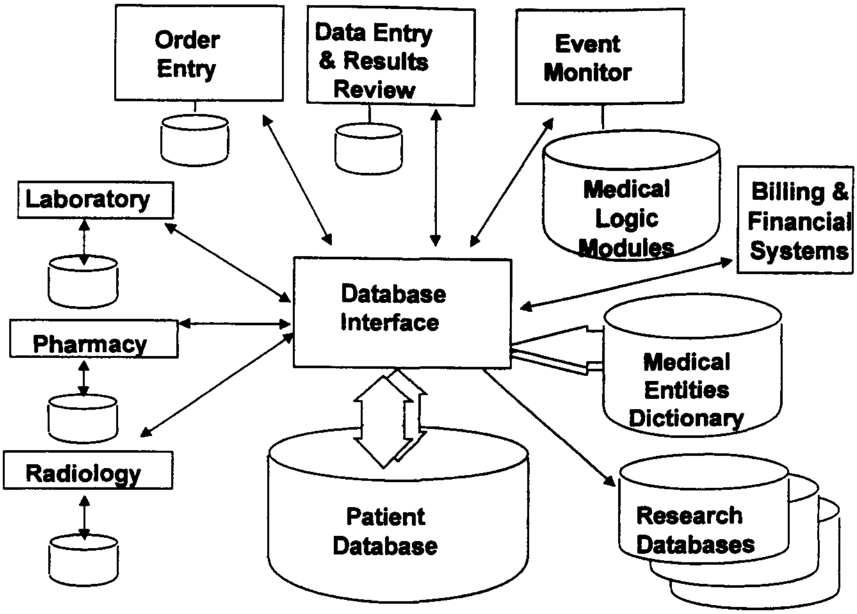


FIGURE 9.1. A block diagram of multiple source-data systems that contribute patient data that ultimately reside in a CPR. The database interface, commonly called an *interface engine*, may perform a number of functions. It may simply be a router of information to the central database. Alternatively, it may provide more intelligent filtering, translating, and alerting functions, as it does at Columbia Presbyterian Medical Center. (*Source*: Courtesy of Columbia Presbyterian Medical Center, New York.)

important for an outpatient clinic visit is shown in Figure 9.2. This summary view of patient data shows the active patient problems, active medications, medication allergies, health-maintenance reminders, and other relevant summary information. Such a view presents a current summary of patient context that is updated automatically at every encounter; such updating is not possible in a paper record.

Cross-platform browsers for finding and viewing information on the Internet (see Chapters 10 and 20) also provide healthcare workers with tools to view patient data from remote systems. Figure 9.3a shows an integrated view of a patient's laboratory-test results from multiple health systems in the city of Indianapolis, which the user sees by using a standard commercial Web browser. Figure 9.3b shows a data-entry screen using a web-browser interface. Advanced security features are required to ensure the confidentiality of patient data transmitted over the public Internet.

9.3.2 Clinical Decision Support

Decision support is most effective when provided at the time that the physician is formulating her assessment of the patient's condition and is making ordering

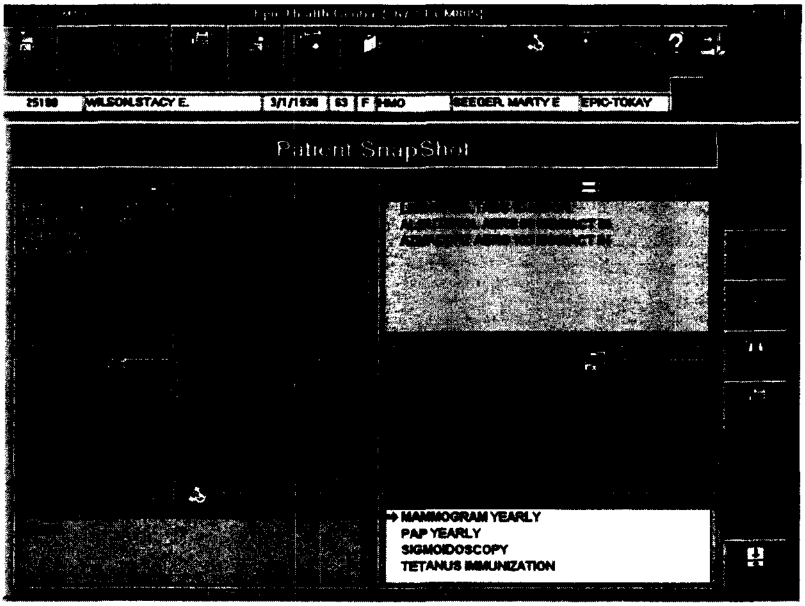
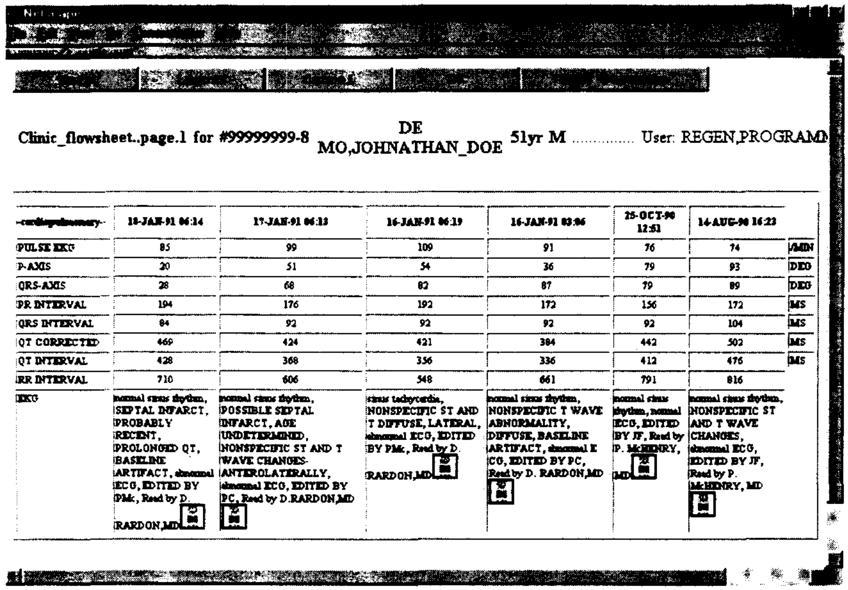


FIGURE 9.2. Quick access to summary information about a patient. The patient's active medical problems, current medications, and drug allergies are among the core data that physicians must keep in mind when making any decision on patient care. An up-to-date snapshot of a patient's context, as depicted in this figure, can save physicians time by providing current information instantly. (*Source*: Courtesy of Epic Systems, Madison, WI.)

decisions. Computer-assisted decision support is only acceptable when it allows the physician to override a system-provided recommendation and choose an alternative action. The most successful decision-support intervention makes complying with the suggested action easy. A brief rationale is generally provided with the recommendation, and complying with the recommendation is as easy as hitting the Enter key or clicking the mouse.

In Figure 9.4, a software module in a large HIS combines information from a variety of data sources regarding a patient's diagnoses and underlying disease and pertinent disease protocols to present recommendations on antibiotic choice, dose, and duration of treatment. Clinicians can view the basis for the recommendations and the logic used. An important part of the program is its solicitation of feedback when the clinician decides not to follow the recommendations. This feedback is used to improve the clinical protocol and the software program. Providing on-line advice on antimicrobial selection has resulted in significantly improved clinical and financial outcomes for patients whose infectious diseases were managed through the use of the program.

Reminders and alerts on a number of matters can be raised during an outpatient encounter as well. Figure 9.5 shows how alerts and reminders are included



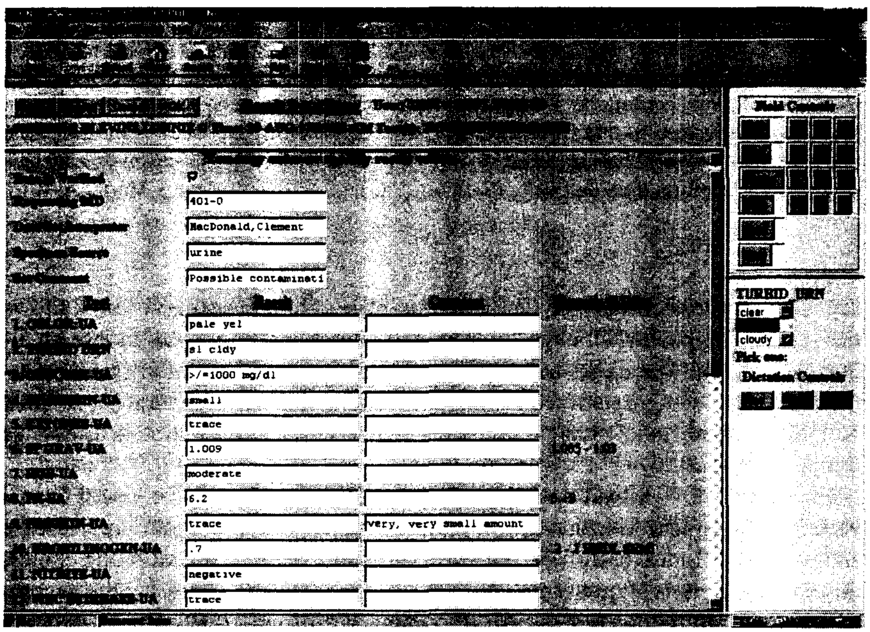


FIGURE 9.3. Web resources. *(a)* Web-browser display of ECG results, measurements, and diagnostic impressions. When the user clicks on the icon, the computer displays the full ECG tracing. (*Source*: Courtesy of Regenstrief Institute, Indianapolis, IN). *(b)* A general data-gathering Web page. The form and content are driven by a set term (in this case *urinalysis*). Digital voice input is allowed on any text field (using dictation controls displayed on the right). The system compresses speech to 270 bytes per second using VOXWARE's algorithm. (*Source*: Courtesy of Regenstrief Institute, Indianapolis, IN.)

```
IHC ANTIBIOTIC ASSISTANT & ORDER PROGRAM

 00000000 Doe, John Q.  E999  57yr  M   Dx:PNEUMONIA
 Max 24hr WBC=16.3  (11.1)   Admit:03/27/97.12.15   Max 24hr Temp=38.3 (37.8)
 RENAL FUNCTION: Decreased,  CrCl= 83,    Max 24hr Cr=1.1  (1.7)   IBW: 79kg
 Patient's Diff shows a left shift, Max 24hr Bands = 16  ( 8)
 ANTIBIOTIC ALLERGIES: Penicillin
 CURRENT ANTIBIOTICS:
 1. 03/27/97.17:23 IMIPENEM/CILASTATIN, (PRIMAXIN) VIAL 500 Q 8 hrs
 IDENTIFIED PATHOGENS              SITE                   COLLECTED
  Staphylococcus coagulase negative   Subclavian           03/28/97.05:00
  Staphylococcus coagulase negative   Blood                03/27/97.15:30
  Staphylococcus aureus           Sputum                   03/27/97.15:21
 ABX SUGGESTION       DOSAGE      ROUTE     INTERVAL
  Vancomycin          1000mg       IV       *q24h   (infuse over 1hr)
 Suggested Antibiotic Duration: 14 days
 * Adjusted based on patient's renal function
  <1>Micro, <2>OrganismSuscept, <3>Drug Info, <4>ExplainLogic, <5>Empiric Abx <6>Abx Hx,
<7>ID Rnds, <8>Lab/Abx Levels, <9>Xray, <10>Data Input Screen<Esc>EXIT, <F1>Help,
<0>User Input, <.>OutpatientModels, <+>Change Patient
 ORDERS:<*>Suggested Abx, <Enter>Abx List, </>D/C Abx, <->Modify Abx
```

FIGURE 9.4. Example of the main screen from the Intermountain Health Care Antibiotic Assistant program. The program displays evidence of an infection, relevant patient data (e.g., kidney function, temperature), and recommendations for antibiotics based on the culture results. (*Source*: Courtesy of R. Scott Evans, Stanley L. Pestotnik, David C. Classen, and John P. Burke, LDS Hospital, Salt Lake City, UT.)

on a preprinted encounter form for use during an outpatient visit. The system searches for applicable decision-support rules and prints relevant reminders on the encounter form during batch printing the night before the scheduled visit. Figure 9.6 shows computer-based suggestions regarding health-maintenance topics and potentially efficacious medications to consider. These suggestions were derived from rules that examine the patient's problems and medications and the timing of laboratory-test orders.

9.3.3 Clinician Order Entry

If the ultimate goal of a CPR system is to help clinicians make informed decisions, then the system should present relevant information at the time of order entry. Several systems have the capability of providing decision support during the order-entry process (Steen, 1996; Tierney et al., 1993). For example, a clinical team in the medical intensive-care unit at Vanderbilt University Hospital can use an electronic chart rack to view active orders and enter new orders. The WIZ Order screen integrates information about a patient's active orders, clinical alerts based on current data from the electronic patient record, and abstracts of relevant articles from the literature. Clinical alerts attached to a laboratory-test result can also include suggestions for appropriate actions (Fig. 9.7).

Providing summary information about the patient's status compared with protocols for which the patient is eligible is another way of providing feedback to the clinician when she is considering her orders (Fig. 9.8).

SAMPLE,PATIENT
05-APR-96 317-630-7400
1001 TENTH ST
INDIANAPOLIS 46202

THU AM 2 Dr: MEGREMIS,JIM G
Wishard Memorial Hospital
1001 W Tenth Street
Indianapolis IN 46202

1 CLINIC VISIT, 2 CLINIC CONSULT, 3 CONSULTATION, 4 ASA EVALUATION, 5 LAB ONLY, 6 RX REFILL, 7 NO CHARGE, 8 MC CLINIC VISIT

---- Diagnoses List ----
1 umbilical hernia
2 thrush
3 seborrhea noe /CRADLE CAP
4 cough
5 throat pain
6 well child
7 otitis media
8 SICKLE TRAIT
9
10

--- Observations List ---
1 HEIGHT PEDS ______INCH
2 WEIGHT PEDS ______LBS
3 TEMP ______DEG F
4 TEMP RECTAL ______DEG F
5 TEMP AXILLARY ______DEG F
6 RR ______/MIN
7 PULSE ______/MIN
8 HEAD CIRCUMF ______CM
9 HEAD CIRC %ILE ______%
10 WT %ILE ______%
11 HEIGHT %ILE ______%
12 SYS BP SITTING ______MM HG
13 DIAS BP SITTING ______MM HG
14 TIME COUNSELING ______MIN
15 TOTAL TIME c PAT______MIN
16*IVH GRADE ______

Notes:

Age:
Informant:

Feedings:
Elimination:
Sleep:
Concerns:

PHYSICAL EXAM:
Normal: Significant Findings:
___ Head
___ Skin
___ Eyes/Vision
___ Ears/Hearing
___ Nose/Throat
___ Teeth/Gums
___ Nodes
___ Chest/Lungs
___ Heart
___ Pulses
___ Abdomen
___ Ext Genitalia
___ Hip Abduct
___ Back
___ Extremities
___ Neuro

DEVELOPMENT:
___ Feeds self, crawls
___ Listens and imitates sound
___ Sits without support
___ Gets to sitting position
___ Feeds self crackers
___ Pulls up
___ Vision observed

SAFETY:
___ Poison control number
___ Syrup of Ipecac
___ Car restraints
___ Safe toys
___ Prevent burns/water heater 125
___ Prevent choking

SOCIAL ASSESSMENT DONE: ______
NUTRITIONAL ASSESSMENT:
WIC: Certified/Letter A
Recert Due: ______
Risk Codes: ___/___/___

PARENTING:
___ Temper tantrums/limits
___ Stranger anxiety,separation anxiety
___ Sleep
___ Reading to child
___ Praise/affection
___ Teeth care

NUTRITION/FEEDINGS:
___ Encourage cup
___ Vit/min supp if indicated

IMPRESSIONS:

PLANS:

------------------------------------ O R D E R S ------------------------------------
* Consider DPT immunization or record previous dates if available.
* Consider OPV immunization or record previous dates if available.
* Consider HEMOPHILUS B VACCINE or record previous dates if available.

Staff: ____________ Signature: ____________

30-JAN-97 Encounter Date	Provider ID	wks months Return	Return Provider	/ / Next Appt Date	PEDIATRICS Service Area

SAMPLE,PATIENT #0999999-6 30-JAN-97 09:15 AM
Printed:20-Jan-97 Page:3
ENCOUNTER FORM OPD-8

FIGURE 9.5. Pediatric encounter form. The questions on these forms vary by age. Reminders for routine immunizations appear at the bottom. (*Source*: Courtesy of Regenstrief Institute, Indianapolis, IN.)

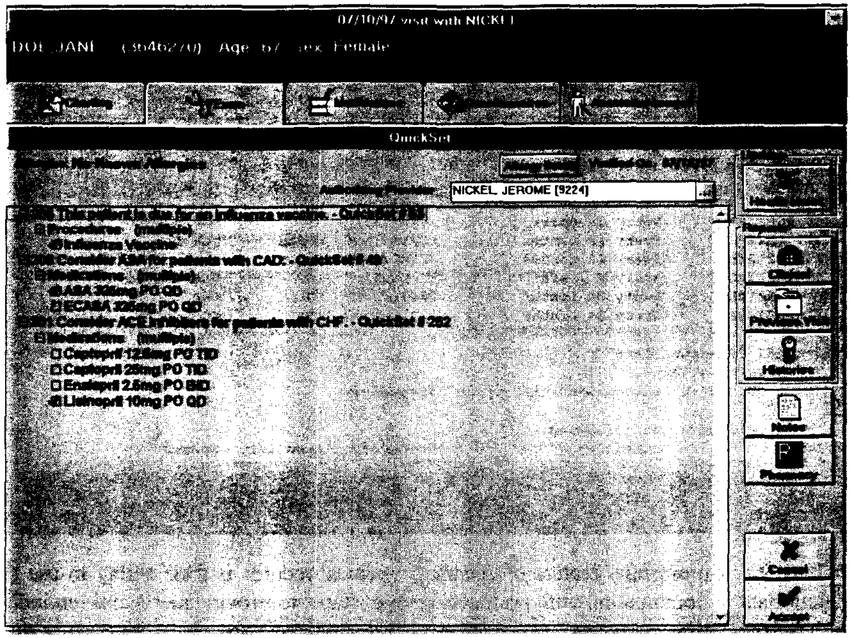


FIGURE 9.6. An example of computer-assisted decision support. The system has examined the patient's problems, medications, age, and health-maintenance record and has determined that she is eligible for certain interventions based on locally approved guidelines. It presents these options for the physician to consider and makes complying with the suggestions as easy as clicking the box (to insert a checkmark). (*Source*: Courtesy of Epic Systems, Madison, WI.)

FIGURE 9.7. Clinical alert. Alerts can be attached to a laboratory-test result. Each time that a laboratory test is completed, a set of rules is checked to determine whether the result is sufficiently abnormal to require further action. In this case, the rule checks for a serum potassium level less than 3.3 mEq/L in a patient taking digoxin. The computer pages the patient's doctor directly; when the doctor responds, the above screen shows the relevant information and offers suggested remedial actions, such as ordering administration of more potassium. (*Source*: Courtesy of Brigham and Womens Hospital, Boston, MA.)

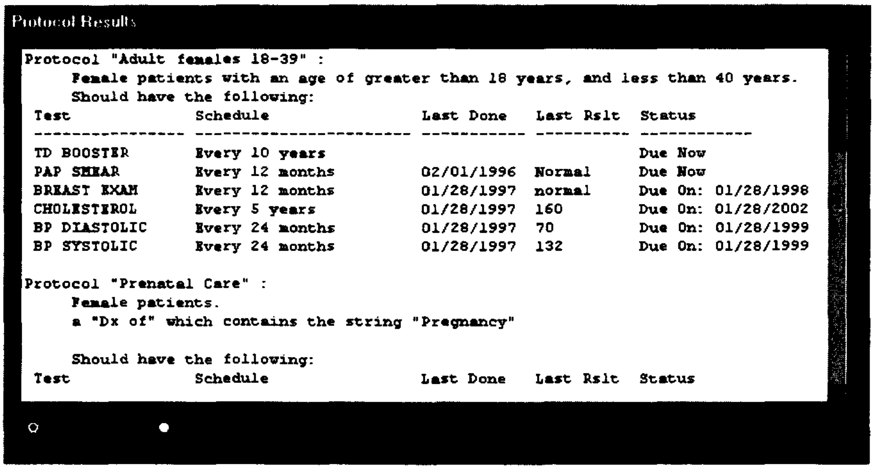


FIGURE 9.8. An essential feature of electronic medical records is their ability to use the patient data in combination with protocols or algorithms to provide alerts and reminders to the clinical decision-makers. Here, an advisory shows preventive services due for adult females in the age range 18 to 39 years, as derived from the United States Public Health Service Preventive Services guidelines. (*Source*: Courtesy of MedicaLogic, Inc., Software: Logician Electronic Medical Record, V.4.5, ©1991–1998, Hillsboro, OR.)

Once a physician order-entry system is adopted into the practice culture, simply changing the default drug or dosing based on the latest scientific evidence can significantly change physician ordering behavior. Clinical quality and financial costs can be changed virtually overnight.

9.3.4 Access to Knowledge Resources

Most queries of knowledge resources, whether they are satisfied by consulting another human colleague or by searching through reference materials or the literature, are conducted in the context of a specific patient (Covell et al., 1985). Consequently, the most effective time to provide access to knowledge resources is at the time decisions or orders are being contemplated by the clinician. Furthermore, any method by which the system can provide preformatted queries that anticipate the clinicians' queries will be helpful and will increase the chance that the knowledge will influence clinicians' decisions. Knowledge resources can also help a clinician to decide whether a referral is appropriate and, if one is, which preconsult tests may expedite the consult process (Fig. 9.9).

9.3.5 Integrated Communication Support

As the care function becomes increasingly distributed among multidisciplinary healthcare professionals, the effectiveness and efficiency of communication among the team members affect the overall coordination and timeliness of care

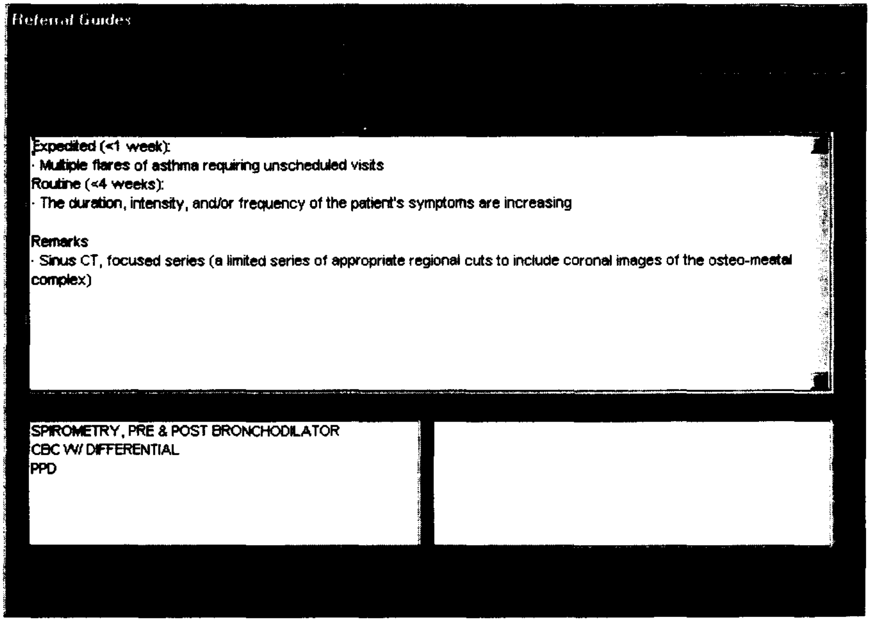


FIGURE 9.9. A CPR linked to knowledge resources so that context-specific information can be displayed at the time of clinical decision-making. For a clinician deciding whether to refer a pregnant patient with asthma to a specialist, a referral guide can provide information that may support decision-making. The guide also may support improved workflow by ensuring that relevant tests and procedures are completed before referral and that unnecessary tests and procedures are avoided. (*Source*: Courtesy of MedicaLogic, Hillsboro, OR.)

provided. Most messages will be associated with a specific patient. Thus, communication tools should be integrated with the CPR system such that messages (including system messages or laboratory-test results) are electronically attached to a patient's record. That is, the patient's record should be available at the touch of a button. Geographic separation of team members creates the demand for networked communication that reaches all sites where providers make decisions on patient care. These sites include the providers' offices, the hospital, the emergency room, and the home. Connectivity to the patient's home will provide an important vehicle for monitoring health (e.g., home blood-glucose monitoring, health-status indicators) and for enabling routine communication.

Figure 9.10 shows an example of a notification message to a primary-care provider that her patient was seen in the emergency room. The patient's complaint and final diagnosis are listed, and the physician can query the system for further information. Notifying the primary-care provider not only provides her with continuity information but also allows her to take proactive steps to follow up on the problem that provoked the unscheduled encounter.

A CPR system can also help with routine patient handoffs, where the responsibility for care is transferred from one clinician to another. Typically, a brief

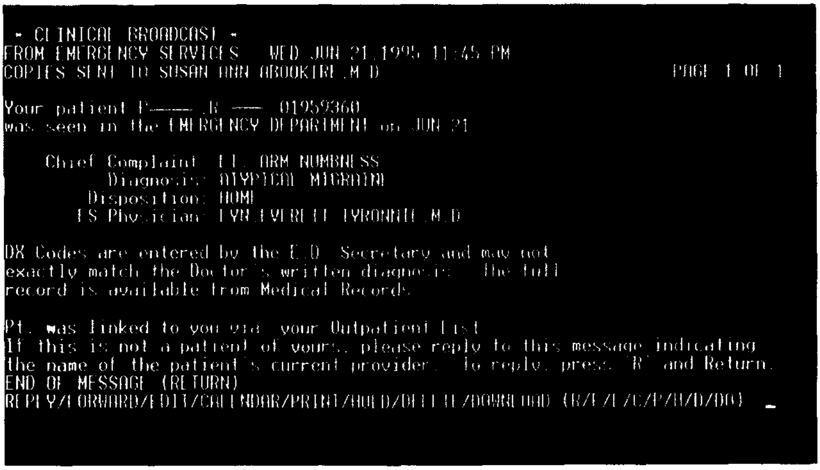


FIGURE 9.10. Communication as part of continuity of care. Whenever a patient completes an emergency-room visit at Brigham and Womens Hospital, an electronic-mail message is sent to the patient's primary provider, outlining the facts of the visit. (*Source*: Courtesy of Brigham and Womens Hospital, Boston, MA.)

verbal or written exchange helps the covering clinician to understand the patient's problems, as is important for making decisions while the primary clinician is unavailable. An example of a screen that contains instructions from the primary physician, as well as system-provided information (e.g., recent laboratory-test results), is shown in Figure 9.11.

Although a patient encounter is usually defined by a face-to-face visit (e.g., outpatient visit, inpatient bedside visit, home health visit), significant information-processing activities occur elsewhere. Responses to patient telephone calls and laboratory-test results are examples of such activities. Ideally, the clinician should be notified of these events and have immediate access to the record to make decisions. Figure 9.12 shows a list of pending information (e.g., new laboratory-test result available, telephone call for a medication refill, telephone call regarding a patient symptom) and buttons linked to information tools that help a clinician to process these new data. The clinician can retrieve the patient's electronic chart, electronically refill a medication, use a template to write a letter informing the patient of normal test results, or dial the patient's telephone number to speak directly with the patient. In addition, when the physician asks the patient to schedule a diagnostic test such as a mammogram, the 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. This tracking function prevents diagnostic plans from falling through the cracks. Communication tools that are integrated with a CPR system provide timely notification of patient events in the context of a patient's record and support transmission of appropriate interventions based on that information.

```
POCKET ROUNDS for WARVEL,JEFF              (29 JUL 97 , 04:47PM)      TEST3, PATIENT           - 123123-0
----------------------------------------------------------------------------------------------------
====================================================================================================
TEST3, PATIENT                               123123-0
====================================================================================================
SEX : M      RACE : B        AGE : 61       ADMIT : 17 JAN 1997        WARD : MCU           BED# : D111
ADMITTING INTERN : TEST,INTERN          MED STUDENT : TEST,STUDENT
CODE STATUS : FULL CODE
PROBLEMS     :    1) cor pulmonale /ACTIVE                         4) COPD /ACTIVE
                  2) CHF /ACTIVE                                   5) cigarette smoker /ACTIVE
                  3) ETOH abuse /ACTIVE                            6) coronary artery disease /ACTIVE
ALLERGIES    :    1) PENICILLINS
ACTIVITIES   :  bed rest, With no exceptions
PRECAUTIONS  :  NO SPECIAL PRECAUTIONS
DIET         :  NPO except meds
CALL ORDERS  :  CALL ORDERS DIAS BP, > 110 mm Hg
                CALL ORDERS PULSE, > 120/min < 50/min
                CALL ORDERS RESP RT, > 30/min
                CALL ORDERS SYS BP, > 190 mm Hg < 90 mm Hg
                CALL ORDERS TEMP, > 101.5 F < 96 F
                CALL ORDERS URINE OUT, <240 cc per shift
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%  REMINDERS  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
 ** Patient on vent: Begin SQ heparin to decrease DVT risk
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
ACTIVE TESTS :
    1) BLD GAS PANEL 1, QAM On 40% oxygen Actv 12 D      5) CXR (PA&LAT), QAM Actv 12 D
    2) BLOOD CELL PROF, QAM Actv 12 D                    6) LYTES, Q AM X indefinitely Actv 12 D
    3) BUN, QAM X indefinitely Actv 5 D                  7) TRIGLYCERIDES Actv 0 D
    4) CREATININE, Draw QAM X indefinitely Actv 5 D
ACTIVE MEDICATIONS :
    1) ALBUTEROL INHL, 4 inhl PO Q4H scheduled. Wait one minute between inhalation, Actv 12 D
    2) ALBUTEROL NEB UNIT DOSE, 1 bottle(3ml) per nebulizer x 1 over 5-15 min per RT -now please, Actv 4 D
    3) ASPIRIN BUFFERED, 325 mg PO QAM -LATE ENTRY, Actv 9 D
    4) CEFTRIAXONE INJ, 1 g IVSP QD -Give first dose now, Actv 5 D
    5) ENTERAL PULMON, Elevate head of bed prior to feeding and hold feeding if residual > 250 ml. Infuse
       50 ml/HOUR of full strength by NG tube.  CHECK RESIDUALS Q4HR. GOAL RATE IS 86 CC/HOUR.  INCREASE BY
       10 CC Q4H IFRESIDUALS ARE OK, Actv 11 D
    6) FE SO4 ELIXIR, 300 mg PO TID AC (iron), Actv 0 D
    7) FOSINOPRIL, 5 mg PO Q day -HOLD FOR SBP < 100, Actv 12 D
    8) HALOPERIDOL INJ, 5 mg iv Q 3 hr -may give an additional 2 mg Q 1 hr prn agitation, Actv 4 D
    9) HEPARIN ARTFLUSH, 1000 units 500 ml LVP inf, Actv 12 D
   10) INHALER SPACER DEVICE, Use with all inhalers, Actv 12 D
   11) IPRATROPIUM INHL, Inhale 4 puffs Q4H, Actv 12 D
   12) IV LOCK (saline flush), WITH ROUTINE FLUSHES, Actv 5 D
   13) LORAZEPAM INJ, 1 mg IV q4h prn agitation., Actv 12 D
   14) NIZATIDINE, 300 mg PO QHS, Actv 12 D
   15) PROPOXYM/ACET 100/650, 1-2 tab PO Q6H PRN pain (maximum of 6 tab/24 hours) -Give first dose now,
       Actv 5 D
ACTIVE OTHER ORDERS :
    1) ANTIEMBOLISM STOCKINGS, to be worn under SCD, Actv 12 D
    2) ARTERIAL LINE, Dressing and heparin flush per routine, Actv 12 D
    3) CARDIAC MONITORING, Continuous monitoring via telemetry or portable monitor, Actv 12 D
    4) CONDOM CATHETER, Apply condom catheter to bedside drainage and measure output Qshift, Actv 5 D
    5) FOLEY CATHETER, Routine nursing care - 07/24/97- May re-anchor foley for decreased urine output
       with condom catheter., Actv 1 D
    6) INTAKE AND OUTPUT, measure all intake and output, Actv 12 D
    7) NEURO CHECKS,  Q2HRS when stable - Q 1HR or more when unstable, Actv 12 D
    8) NG TUBE, Place for medication to gravity, Actv 12 D
    9) OXYGEN THERAPY, Give continuously via Re-breather mask, Use 100% O2 with target oxygen saturation
       of 92% per oxygen titration protocol -- WEAN AS TOLERATED, Actv 4 D
   10) PEAK FLOW, measure and record before and after bronchodilator treatments x7 days then during an
       exacerbation and seek medical care if you cannot reach 80% of your baseline, Actv 4 D
   11) PERCUSSION AND DRAINAGE, Perform to bilateral base q4, Actv 4 D
   12) SEQUENTIAL COMPRESSION DEVICE, Apply to both leg(s) prevent thrombophlebitis, Actv 12 D
   13) VENTILATOR FIO2, 45%, Actv 12 D
   14) VENTILATOR MODE, synchronized IMV, Actv 12 D
   15) VENTILATOR PEEP, 5 cm H2O, Actv 12 D
   16) VENTILATOR PRESSURE SUPPORT, 10 cm H2O, Actv 12 D
   17) VENTILATOR RATE, 6 breaths/min, Actv 12 D
   18) VENTILATOR SETTINGS - (See detailed settings), Actv 12 D
   19) VENTILATOR TIDAL VOL, 800 ML, Actv 12 D
   20) VITALS (TPR&BP), Actv 12 D
   21) WEIGHT KGS, weigh daily, Actv 12 D
STANDARD PARAMETERS :
```

YEAR	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997
DAY-MONTH	29 JUL	29 JUL	28 JUL	27 JUL	27 JUL	27 JUL	26 JUL	26 JUL	26 JUL	25 JUL	25 JUL
HOUR	10:29	04:57	04:28	21:27	17:02	04:30	21:02	20:56	04:14	20:21	20:20
CHEM12											
BUN	-	15	27 h	29 h	-	30 h	30 h	-	21	20	-
GLUCOSE	-	102	81	-	-	109	101	112 h	-	-	128 h
CREATININE	-	0.6	0.7	0.7	-	0.8	1.0	-	0.7	0.7	-
LYTES											
SODIUM	-	140	138	139	-	138	139	-	139	140	-
POTASSIUM	-	4.3	4.8	4.5	-	5.0	4.4	-	4.0	4.5	-
CHLORIDE	-	100	101	102	-	99	102	-	97	97	-

Page 5

FIGURE 9.11 The popular Pocket rounds reports. When folded in half, these reports fit in the pocket of a clinician's white coat. (*Source*: Courtesy of Regenstrief Institute. Indianapolis, IN.)

POCKET ROUNDS for WARVEL,JEFF (29 JUL 97 , 04:47PM) TEST3, PATIENT - 123123-0

YEAR	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997
DAY-MONTH	29 JUL	29 JUL	28 JUL	27 JUL	27 JUL	27 JUL	26 JUL	26 JUL	26 JUL	25 JUL	25 JUL
HOUR	10:29	04:57	04:28	21:27	17:02	04:30	21:02	20:56	04:14	20:21	20:20
LYTES (continued)											
CO2 (TOTAL)	-	32 h	30 h	29 h	-	31 h	31 h	-	33 h	34 h	-
BLOOD CELL PROF											
WBC	-	7.2	6.5	-	-	6.2	-	-	7.2	-	-
RBC	-	4.5	4.7	-	-	4.7	-	-	4.9	-	-
HGB	-	10.9 l	11.1 l	-	-	10.8 l	-	-	11.6 l	-	-
HCT	-	35 l	36 l	-	-	35 l	-	-	37 l	-	-
MCV	-	76 l	76 l	-	-	75 l	-	-	75 l	-	-
MCH	-	24 l	24 l	-	-	23 l	-	-	24 l	-	-
MCHC	-	32	31 l	-	-	31 l	-	-	32	-	-
RDW (CSH)	-	19.1 h	19.1 h	-	-	18.9 h	-	-	18.7 h	-	-
CREATININE URIN£	-	-	-	-	194	-	-	-	-	-	-
LYTES RANDOM URINE											
NA+ R-URN	-	-	-	-	21	-	-	-	-	-	-
K+ R-URN	-	-	-	-	69	-	-	-	-	-	-
CL R-URN	-	-	-	-	49	-	-	-	-	-	-
TRIGLYCERIDES	(a)	-	-	-	-	-	-	-	-	-	-

a) 124 Specimen Slightly Hemolyzed

YEAR	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997
DAY-MONTH	29 JUL	29 JUL	28 JUL	28 JUL	27 JUL	27 JUL	26 JUL	26 JUL	26 JUL	26 JUL	26 JUL
HOUR	11:14	10:53	10:46	04:06	21:20	15:41	23:47	10:57	06:41	05:05	01:10
VITALS											
TEMP AUTO ORAL	-	-	-	-	-	98.6	-	98.4	-	-	-
PULSE AUTO	-	66	72	-	-	78	-	74	-	-	-
RESP RATE AUTO	-	19	8 L	-	-	16	-	16	-	-	-
SYSTOLIC BP AU£	-	116	108	-	-	102	-	123	-	-	-
DIASTOLIC BP A£	-	73	68	-	-	62	-	74	-	-	-
WEIGHT VITALMET	-	(a)	(b)	-	-	(c)	-	(d)	-	-	-

a) 281.52 h
b) 289.02 h
c) 286.59 h
d) 278.88 h

BLD GAS PANEL 1											
PH BLD	7.332 l	-	-	7.360 l	7.381	-	7.373 l	-	7.370 l	7.380	7.398
PCO2	59.5 H	-	-	52.1 h	46.4 h	-	45.7 h	-	61.7 H	48.8 h	53.3 h
PO2	73.0 l	-	-	92.0	65.0 l	-	55.0 l	-	103.0 h	57.0 l	71.0 l
BICAR(HCO3) CA£	31.9 h	-	-	29.7 h	27.8 h	-	26.9 h	-	36.0 h	29.1 h	33.2 h
CO2 TOTAL CALC	33.7 h	-	-	31.3 h	29.2 h	-	28.3 h	-	37.9 h	30.6 h	34.8 h
INSPIRED O2	40	-	-	50	50	-	45	-	50	45	45

YEAR	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997
DAY-MONTH	28 JUL	26 JUL	25 JUL	24 JUL	23 JUL	22 JUL	21 JUL	20 JUL	18 JUL	17 JUL	17 JUL
HOUR										17:02	00:02
ABDOMEN XRAY	-	-	-	-	-	-	-	-	-	(a)	-

a) HOSP NG tube; bibasilar; right pleural effusion

EXTREMITY ULTR£	-	-	-	-	-	-	-	-	-	-	(a)

a) HOSP no DVT

CXR FRONTAL	-	(a)	(b)	(c)	(d)	(e)	(f)	(g)	-	-	-

a) 1. Slight interval improvement in pulmonary edema.
b) Slight increase in amount of opacity in the right lower lobe, could represent alveolar edema.
c) 1. Bilateral lung infiltrates, which appear slightly improved. 2. Improved right upper lobe atelectasis.
d) New opacification of the right upper lobe since this morning. This may represent a volume loss vs. a consolidation.
e) Slight improvement in bilateral lung infiltrates.
f) Interval improvement in lung aeration bilaterally.
g) 1. No change in lines and tubes. 2. Slight increase in right effusion and bilateral diffuse infiltrates consistent with pulmonary edema.

XRAY OTHER	(a)	-	-	-	-	-	-	-	-	-	-

a) Interval increase in lung infiltrates, most consistent with pulmonary edema.

CXR LAT DECUBI£	-	-	-	-	-	-	-	-	(a)	-	-

a) Large layering right effusion.

CHEST CT SCAN	-	-	(a)	-	-	-	-	-	-	-	-

a) 1. Bilateral lower lobe partial atelectasis and infiltrate. 2. Small right effusion. 3. Mid atelectasis in the posterior segment of the right upper lobe. There is a few 1 cm to 1.5 cm right peritracheal lymph node.

FIGURE 9.11 (Continued).

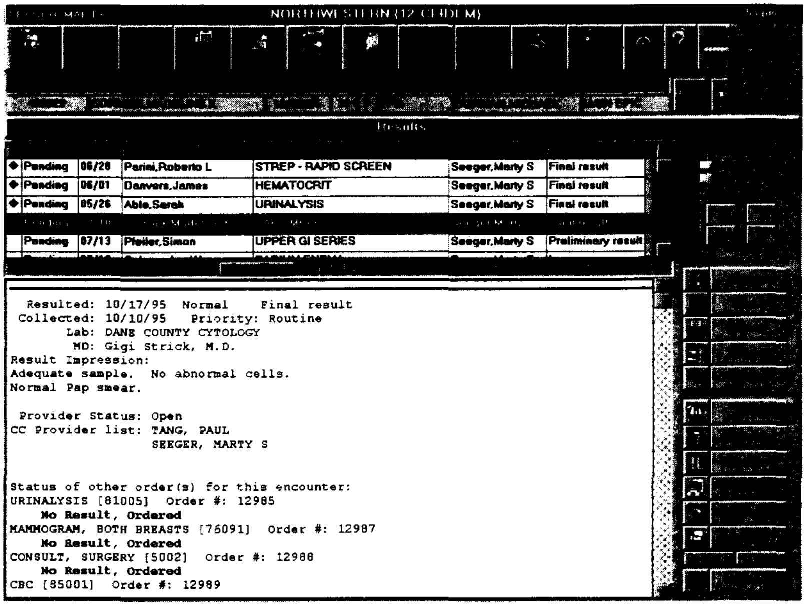


FIGURE 9.12 Prompt notification of laboratory test results. When a messaging system is integrated with the CPR system, test results can be directed to the provider's in-basket as soon as they are available. By clicking on the Review button at the lower right corner, the clinician can retrieve the patient's CPR instantly and with it any relevant information that she reviewed before acting on the most recent result or message. Telephone messages and other patient-related information can be handled in the same manner. (*Source*: Courtesy of Epic Systems, Madison, WI.)

9.4 Fundamental Issues for Computer-Based Patient-Record Systems

The objectives of all medical-record systems are the same, regardless of whether the system is automated or manual. The mechanisms for accomplishing these objectives differ, however. From a user's perspective, the two approaches differ fundamentally in the way data are entered into and information is extracted from the record. In this section, we explore the issues and alternatives related to data entry and then describe the options for displaying and retrieving information from a CPR.

9.4.1 Data Entry

The timely and accurate transfer of patient information into the computer is the most difficult and labor-intensive step in the maintenance of a computer-stored medical record. Yet this step has not received enough attention by developers and potential buyers of such systems, because responsibility for entry of data into the manual record is spread among many different health professionals and because the task is such a habitual part of their daily routines that it is almost invisible.

The transfer of data from its source to the computer requires two separate procedures: data capture and data input.

Data Capture

If the *scope* of the medical record is restricted to the variables under the control of the organization maintaining the record, **data capture** is straightforward, although it requires people's time and resources to interface the data-source systems with the CPR. Capture of comparable information across a patient's hospitalization, visit to the emergency room, and visit to a consulting physician in an independent practice is difficult or impossible. Relevant information may go unnoticed (e.g., the patient fails to mention a recent hospitalization); it may be illegible (e.g., the data recorded on the third carbon of the emergency-room visit form are not legible); or it may be available in insufficient detail (e.g., the consulting physician reports that all the patient's test results were normal but does not specify the tests' actual values). Solutions require personal negotiations with sites that frequently provide care to a practice's patients and place extra work on the part of the practice.

It may be practical to restrict the scope of the medical record to information that is returned to the practice—but such restrictions can limit the computer program's ability to provide intelligent feedback about patient care. A computer system in a medical clinic, for example, cannot make accurate recommendations about the need for cervical Pap testing if most cervical Pap results are requested by, and returned to, a consulting gynecologist from an independent practice group. The clinic would need to develop special procedures to obtain copies of those reports for entry into the medical clinic's computer. Similarly, inpatient CPR systems are constrained in their ability to generate alerts and reminders if data collected in one department are inaccessible to another department. The trend toward larger, more integrated, and more self-contained health-care systems will tend to diminish the problem of data capture. Nevertheless, the standards required to move data faithfully and automatically from source systems to CPRs within a healthcare delivery system remain a significant challenge (see Chapters 6 and 10).

Data Input

The data-input step is burdensome because of the personnel time required. People must interpret or translate the data, as well as enter them into the computer. Data may be entered in **free-text** form, in **coded** form, or in a form that combines both free text and codes. In Chapter 6, we described alternative schemes for classifying diagnoses and medical procedures. The major advantage of coding is that data are classified and standardized, thus facilitating selective retrieval of patient data, clinical research, and information for administrative functions such as billing. Coding lets the computer "understand" the data and thereby process them more intelligently. When there are only a few codes, a selection list can simplify the data input. The major disadvantage of coding is the cost of translating the source text into valid codes. There also is the potential for coding errors—which, in contrast to errors in free-text entry, are difficult to detect, because coded information lacks the internal redundancy of text. For example, a transposition error causing a substitution of code 392 for 329 may not be detected unless the computer displays the associated text and the data-entry operator notices the error.

Trade-offs between the use of codes and narrative text exist. Physicians can record complex information as narrative writing or dictation at the speed of thought. The more detailed the coding system and the more precisely the physician tries to represent a complex description in code, the slower and more costly the coding effort becomes.

Immediate coding by physicians (best through menu selection) yields codes that the CPR can use to guide physicians' decisions. If menus are carefully designed, their use will be more accurate than coding by other personnel. The use of trained coders to abstract physician's notes, however, has the advantages of sparing the physician's time and often of yielding more uniform coding. Various computer sources of coded data, including laboratory systems, pharmacy systems, and electrocardiogram (ECG) carts, exist in health-care settings. Data from these systems can flow automatically to the CPR through message standards such as HL7 (described in Chapter 6). Here, the challenge is the variety of local coding systems. The solution is to use standard coding systems—such as LOINC for identification of laboratory tests and clinical measurements (Forrey et al., 1996) and (in the United States) the National Drug Code for identification of drug products.

Error Prevention

Because of the chance of transcription errors occurring when clinical information is entered into the computer, CPR 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 mEq/L—the normal range for healthy individuals is 3.5 to 5.0 mEq/L). **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 pounds in 2 weeks). **Spelling checks** verify the spelling of individual words. No such syntactic checks can catch all errors.

Physician-Entered Data

Physician-gathered patient information requires special comment because it presents the most difficult challenge to developers and operators of CPR systems. Physicians record four kinds of information:

1. Patient histories
2. Physician's findings from the physical examination
3. Physician's interpretation of the patient's findings
4. Physician's diagnostic and treatment plans

Physicians' notes can be entered via one of three general mechanisms: transcription of dictated or written notes, entry of data recorded on structured encounter forms, or direct data entry by physicians (direct entry may include use of electronic structured encounter forms). Dictation and **transcription** is a common option for data entry of textual information into CPRs because it is widely and comfortably used by physicians. This method is especially attractive when the practice has already invested in dictation services, because then the cost of keying already has been absorbed. If physicians dictate their reports using standard formats (e.g., present illness, past history, physical examinations, and treatment plan), then the transcriptionist maintains this structure in the transcribed document. Furthermore, digital voice dictation itself can also be stored in the CPR and retrieved without transcription, especially with existing and efficient (20:1 real time) data compression algorithms. However, the recorded note must be played back in real time; a clinician cannot skim a recording looking for specific information. In addition, transcription is associated with delays before the notes are available and carries the requirement that the author review, correct, and sign the note. All these steps leave room for errors and delays in completing the record. Interestingly, when CPRs with text-entry capability are introduced into a practice whose members usually dictate their notes, many physicians will choose to type their notes directly into the computer.

The second data-entry method is to have physicians use a **structured encounter form** from which their notes are transcribed (and possibly encoded) by support personnel. This approach has been the most successful to date. The RMRS uses highly tailored turnaround encounter forms (see Figure 9.5) to capture coded information; some forms are tailored to specific patient problems. Encounter forms often contain checklists of common signs, symptoms, and diagnoses, fields where required information may be filled in, and space for free-text comments.

The third alternative is the **direct entry** of data, by a physician, via a computer. Physicians do enter orders directly in some hospitals. Direct order entry can be facilitated by custom menus that contain standing orders for specific problems (e.g., postoperative orders for patients who undergo coronary-artery bypass operations). Menus must be carefully structured; they must not contain lists that are too long, require scrolling, nor impose a rigid hierarchy (Kuhn et al., 1984). Direct entry of the patient's history, physical findings, and progress notes has been challenging because of the extra time it takes the physician to enter such information into the computer compared with scribbling a note. Some physicians who have adopted CPRs into their practice (and consequently do have the complete record available, including progress notes), however, value the benefits of immediate and remote access to their patients' records and consider the initial data-entry time worth the benefits on the retrieval side (Tang & McDonald, unpublished data). **Computer interpretation** of voice input holds promise to eliminate the intermediate step of human transcription because it could permit the computer to understand oral commands and to translate them into the appropriate codes or text. Furthermore, **continuous-speech recognition** has been successful in limited domains (e.g., radiology reports, emergency room visit notes). We expect that speech recognition will eventually alleviate the problem of physician data entry, at least for narrative text, and that early implementations will combine transcription services and speech recognition to speed the transcription process.

9.4.2 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. We discuss a few helpful formats.

Flowsheets of Patient Data

A **flowsheet** is similar to a spreadsheet; it organizes patient data according to the time that they were collected, thus emphasizing changes over time. For example, a flowsheet used to monitor patients who have hypertension (high blood pressure) might contain values for weight, blood pressure, heart rate, and doses of medications that control hypertension. Other pertinent information also could be added, such as results of laboratory tests that monitor complications of hypertension itself or of medications used to control hypertension. Flowsheets are designed to be problem specific, patient specific, or specialty specific. The time granularity may change from one setting to another. For example, when a patient is in the intensive-care unit (ICU), minute-to-minute changes in the patient's clinical state may be of interest. On the other hand, an outpatient physician is more likely to want to know how that patient's data have changed over weeks or months. For convenience of human review, the temporal granularity should be appropriate to the intensity of care. Thus, measurement of blood pressures every 20 minutes in an ICU is not of interest to the physician taking care of the same patient later in the clinic after the patient's condition is stabilized.

Summaries and Abstracts

Computer-based patient records can highlight important components (e.g., active allergies, active problems, active treatments, and recent observations) in a clinical summary (Tang et al, 1999). In the future, we can expect more sophisticated summarizing strategies, such as detection of significant changes in observations or aggregation of abnormal observations with a similar meaning (e.g., elevated SGOT, elevated alkaline phosphate, and elevated bilirubin, all of which are indicators of liver dysfunction) into a summary diagnostic statement. We may also see reports that distinguish abnormal changes that have been treated from those that have not and displays that dynamically organize the supporting evidence for existing problems. Ultimately, computers should be able to produce concise and flowing summary reports that are like an experienced physician's hospital discharge summary.

Turnaround Documents

Turnaround documents are computer-tailored reports that both present information to and ask questions of the user. They are the paper equivalent of an input screen on a computer. Visit encounter forms (see Fig. 9.5) can be used as both patient information summary sheets and structured data-input forms. In some settings (Teich, 1997), these forms are entered into the computer when completed. A well-structured turnaround document allows direct capture of clinical information from physicians in many environments. Paper turnaround documents are familiar materials, and people can use them with little training. Obviously, turnaround documents have their greatest application in outpatient care, where there is sufficient time to prepare them before patient visits. They also have been used on inpatient units—for example, to gather drug-administration information and notes from nurses—and as request forms for diagnostic studies. Direct input by clinicians into forms provided on a computer will soon replace most paper intermediaries.

Dynamic Displays

Anyone who has reviewed a patient's chart knows how hard it can be to find a particular piece of information, such as what the interpretation was of the most recent computed tomography scan—or whether one ever was done. From 10 percent (Fries, 1974) to 81 percent (Tang et al., 1994b) of the time, physicians do not find patient information that has been previously recorded and belongs in the 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 in the past, and how the patient has responded to particular treatments 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 help the physician to locate relevant data, and specialized presentation formats (e.g., flowsheets or graphics) make it easier for them to glean information from the data. Special displays can identify problem-specific parameters to help the physician retrieve relevant information, and a graphical presentation can help the physician to assimilate the information quickly and to draw conclusions (Tang et al., 1994b). Click-and-expand technology, now common on Web pages, will simplify such tasks by using a paradigm that is becoming familiar to everyone.

9.4.3 Query and Surveillance Systems

The query and surveillance capabilities of computer-stored records have no counterpart in manual systems. Medical personnel and administrators can use these capabilities to generate alerts about important clinical events, to retrieve a patient's selected medical or administrative characteristics, and to summarize information statistically. **Query** is the retrieval and aggregation of data about groups of similar patients. **Surveillance** across subgroups of patients is the detection and flagging of patient conditions that warrant medical attention.

Although these functions are different, their internal logic is similar. In both, the central procedure is to examine a patient's medical record and, if the record meets prespecified criteria, to generate an appropriate output. Query generally addresses a large subset or all of a patient population; the output is a tabular report of selected raw data on all the patient records retrieved or a statistical summary of the values contained in the records. Surveillance generally addresses only those patients under active care; its output is an **alert** or **reminder message** (McDonald, 1976), such as the message shown in Figure 9.13.

FIGURE 9.13 Display of suggested orders that appears during a physician order-entry session. The suggestions for heparin drip and warfarin arise because the patient has deep venous thrombosis. The suggestion for fosinopril arises because the patient has systolic dysfunction by echocardiography and has no contraindications to angiotensin-converting enzyme inhibitors. (*Source*: Courtesy of Regenstrief Institute, Indianapolis, IN.)

Query and surveillance systems can be used for clinical care, clinical research, retrospective studies, and administration.

Clinical Care

Computer reminders have increased substantially physicians' use of preventive care for eligible patients. Surveillance systems can identify patients who are due for periodic screening examinations such as immunizations, breast examinations, and cervical Pap tests and can remind physicians to perform these procedures during the next visit. For example, physicians given computer reminders quadrupled the use of certain vaccines in eligible patients compared with those who did not receive reminders (McDonald et al., 1984a; McPhee et al., 1991). Query systems are particularly useful for conducting ad hoc searches—for example, to identify and contact patients who have been receiving a drug that is recalled from the market. These systems also can facilitate the completion of quality-management activities, such as accreditation-required care reviews. They can identify candidate patients for concurrent review and can gather many of the data required to complete such audits.

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 were male, were over 50 years of age, and were taking antihypertensive medication. Surveillance facilities can support the execution of a study by tracking patients through their visits and by following the steps of a clinical trial as described in the study protocol to ensure that treatments are given and measurements obtained when required.

Retrospective Studies

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

Computer-based patient record systems can provide many of the data required for a retrospective study. They can, for example, identify study cases and comparable control cases, and they can perform the statistical analyses needed to compare the two groups (Bleich et al., 1989; McDonald & Tierney, 1986a).

Computer-stored records do not eliminate all the work required to complete an epidemiologic study; chart reviews and patient interviews may still be necessary if some patient information is recorded as narrative text. The more information that can be retrieved from the record, however, the less frequently and less intensively such time-consuming tasks must be conducted. 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.

Administration

As we discuss in Chapter 19, managed care and fixed-cost reimbursement for specific diseases (diagnosis-related groups, or capitation payments) and competitive bidding for healthcare contracts provide incentives for administrators to consider clinical as well as cost information in deciding what services to market, to whom, and at what price. In addition, administrators must be able to monitor physicians' use of resources for various classes of patients and to provide appropriate feedback for physicians whose behavior is significantly different from the norm. Medical query 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.

9.5 Challenges Ahead

Although many commercial products are labeled as CPR 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 a CPR is neither unified nor static. As the capability of technology evolves, the function of the CPR will expand. 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 CPR systems currently in use.

The future of CPR systems depends on both technical and nontechnical considerations (McDonald, 1997a). Hardware technology will continue to advance, with processing power doubling every two years according to Moore's law. Software will improve with more powerful applications, better user interfaces, and more integrated decision support. Perhaps the greater need for leadership and action will be in the social and organizational foundations that must be laid if CPRs are to serve as the information infrastructure for health care. We touch briefly on these challenges in this final section.

9.5.1 Users' Information Needs

We discussed the importance of clinicians directly using the CPR system to achieve maximum benefit from computer-supported decision-making. Consequently, developers of CPR systems must thoroughly understand clinicians' information needs and workflows in the various healthcare settings. 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., 1994a). Regrettably, most clinical systems in use now cannot answer many of the common questions that clinicians ask. Developers of CPR systems must have a thorough grasp of users' needs if they are to produce systems that help healthcare providers to use these tools efficiently to deliver care effectively.

9.5.2 User Interfaces

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 if they are to build interfaces that are intuitive and functional. Improving human–computer interfaces will require changes not only in how the system behaves but also in how humans interact with the system. We are learning much from the ubiquity of Web interfaces. 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 humans to formulate insightful questions and to interpret data is still a rate-limiting step (Tang & Patel, 1993). User interface requirements of clinicians entering patient data are different from the user interfaces developed for clerks entering patient charges. Healthcare applications developers must now focus on specific sets of users (such as clinicians, nurses, and so forth) and must define and address their unique information needs.

9.5.3 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 were discussed in Chapter 6. Here, we stress the critical importance of national standards in the development, implementation, and use of CPR systems (McDonald et al., 1997). Having standards reduces development costs, increases integration, and facilitates the collection of meaningful aggregate data for quality improvement and health-policy development. Leadership from stakeholders in health care is critical to achieving useful standards. The need for consistent standards throughout the United States, and ideally around the world, requires action and participation of our federal and other countries' governments. Legislation that mandates certain standards has already been enacted (Barrows & Clayton, 1996). Further enabling legislation will be necessary. Those who wish to implement CPRs should promote and adopt clinical information standards.

9.5.4 Legal and Social Issues

In addition to legislation on standards, federal laws and guidelines on other aspects of the use of CPR systems must be established before widespread adoption will occur. Privacy, confidentiality, and security are major areas of concern in CPRs. Federal regulations are needed, because patients and their data pass freely among states, which currently have greatly differing requirements (see Chapter 7). Europe has adopted strict regulations, although their enforcement is spotty. Adequate methods must be defined and legally enforced to protect the private data of our citizens. With appropriate laws and policies, however, computer-stored data can be more secure and confidential than those data maintained in paper-based records (Barrows & Clayton, 1996).

9.5.5 Costs and Benefits

The Institute of Medicine declared the CPR an essential infrastructure for the delivery of health care (Institute of Medicine Committee on Improving the Patient Record, 1997). 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. Part of the difficulty in comparing costs and benefits of a CPR is our inability to measure accurately the actual costs and opportunity costs of using paper-based records. Many randomized controlled clinical studies have shown that computer-based decision-support systems that are integrated in a CPR reduce costs and improve quality compared with usual care supported with a paper medical record (Bates et al., 1997; Classen et al., 1997; Tierney et al., 1993). It is difficult, however, to determine the scalability and longevity of such benefits.

Because of the significant resources needed and the significant broad-based potential benefits, the decision to implement a CPR 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.

9.5.6 Leadership

Leaders from all segments of the healthcare 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 CPR systems in health care. 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 CPR systems and work to overcome the obstacles that impede widespread use of computers for the benefit of health care.

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.

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.

Institute of Medicine Committee on Improving the Patient Record. (1997). *The Computer-Based Patient-Record: An Essential Technology for Health Care* (2nd ed). Washington, D.C.: National Academy Press.

This landmark study by the Institute of Medicine defines the CPR, describes the users and uses of the medical record, examines technologies employed in CPRs, and recommends actions to accelerate the development and routine use of CPRs in the United States. The second edition adds commentaries on the status of CPRs in the United States and Europe 5 years after the release of the original report.

McDonald C.J. (Ed.) (1988). Computer-stored medical record systems. *MD Computing*, 5(5):1–62.

This issue of *MD Computing* contains invited papers on the STOR, HELP, RMRS, and TMR systems. The objective of the issue is to describe the design goals, functions, and internal structure of these established, large-scale CPR systems.

McDonald C.J., Tierney W.M. (1986). The medical gopher: A microcomputer system to help find, organize and decide about patient data. *Western Journal of Medicine*, 145(6):823–829.

McDonald and Tierney describe research conducted at the Regenstrief Institute for Health Care in developing a PC-based medical workstation that can help physicians to organize, review, and record medical information.

Osheroff J. (Ed.) (1995). *Computers in Clinical Practices. Managing Patients, Information, and Communication.* Philadelphia: American College of Physicians.

This text looks at the practical use of computers in the office practice with a special emphasis on medical records.

Pryor T.A., Gardner R.M., Clayton P.D., Warner H.R. (1983). The HELP system. *Journal of Medical Systems*, 7(2):87–102.

This article summarizes the HELP system's objectives and describes HELP's use in clinical decision-making.

Van Bemmel J.H., Musen, M.A. (1997). *Handbook of Medical Informatics*. Heidelberg: Bohn Stafleu Van Loghum, Houten.

This book provides a comprehensive survey of work being performed to develop information technology for the clinical workplace.

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 a CPR? Define a CPR system. What are five advantages of a CPR over a paper-based record? What are three limitations of a CPR?
2. What are the five functional components of a CPR? Think of the information systems used in healthcare 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 could 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. How does the healthcare financing environment affect the use, costs, and benefits of a CPR system? How has the financing environment affected the functionality of information systems? How has it affected the user population?
5. Would a computer scan of a paper-based record be a CPR? What are two advantages and two limitations of this approach?
6. Among the key issues for designing a CPR system are what information should be captured and how it should be entered into the system.
   a. 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?
   b. Discuss the relative advantages and disadvantages of entry of free text instead of entry of fully coded information. Describe an intermediate or compromise method.
7. Identify four locations where clinicians need access to the information contained in a CPR. What are the major costs or risks of providing access from each of these locations?
8. What are three important reasons to have physicians enter orders directly into a CPR system? What are three challenges in implementing such a system?
9. Consider the task of creating a summary report for clinical data collected over time and stored in a CPR 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.

10. 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 a CPR. How do the risks of privacy breaches differ for the two systems?