4

Electronic Health Records

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LEARNING OBJECTIVES

After reading this chapter the reader should be able to:

- Explain the definition and history of electronic health records (EHRs)
- Describe the limitations of paper-based health records
- Identify the benefits of electronic health records
- List the key components of an electronic health record
- Describe the ARRA-HITECH programs to support electronic health records
- Describe the benefits and challenges of computerized order entry and clinical decision support systems
- State the obstacles to purchasing, adopting and implementing an electronic health record
- Enumerate the unintended adverse consequences related to EHRs

INTRODUCTION

There is no topic in health informatics as important, yet controversial, as the electronic health record (EHR). Attempts at developing and promoting EHRs go back over 40 years. However, only in recent years have EHRs become firmly rooted in the US Healthcare system. Despite their widespread recent adoption, they are very much a work in progress.

The Problem Oriented Medical Information System (PROMIS) was developed in 1976 by The Medical Center Hospital of Vermont in collaboration with Dr. Lawrence Weed, the originator of the problem oriented record and subjective, objective, assessment and plan (SOAP) formatted notes. Ironically, the inflexibility of the concept led to its demise.[1] In a similar time frame, the American Rheumatism Association Medical Information System (ARAMIS) appeared. All findings were displayed as a flow sheet. The goal was to use the data to improve the care of rheumatologic conditions.[2] Other EHR systems began to appear throughout the US: the Regenstrief Medical Record System (RMRS) developed at Wishard Memorial Hospital, Indianapolis; the Summary Time Oriented Record (STOR) developed by the University of California, San Francisco; Health Evaluation Through Logical Processing (HELP) developed at the Latter Day Saints Hospital, Salt Lake City and The Medical Record developed at Duke University,[3] the Computer Stored Ambulatory Record (COSTAR) developed by Octo Barnett at Harvard and the De-Centralized Hospital Computer Program (DHCP) developed by the Veterans Administration.[4]

In 1970 Schwartz optimistically predicted, "*clinical computing would be common in the not too distant future*."[5] In 1991, the Institute of Medicine (IOM) (now known as the National Academy of Medicine) recommended EHRs as a solution for many of the problems facing modern medicine.[6] However, following the IOM recommendation, little progress was made for multiple reasons. As Dr. Donald Simborg stated, the slow early acceptance of EHRs was like the "*wave that never breaks*."[7]

The Health Information Technology for Economic and Clinical Health (HITECH) Act that was part of the American Recovery and Reimbursement Act (ARRA) of 2009 was a game changer for EHRs, with incentive programs established by the Centers for Medicare & Medicaid Services (CMS) for the "meaningful use" of certified EHRs utilizing defined criteria to specify eligibility and objectives, as well as other programs that supported EHR education and health information exchange. The EHR incentive program will be discussed in more detail later in this chapter.

In this chapter, we will primarily discuss outpatient (ambulatory) electronic health records, including logical steps to selecting and implementing an EHR.

Electronic Health Record Definitions

There is no universally accepted definition of an EHR. As more functionality is added the definition will need to be broadened. Importantly, EHRs are also known as electronic medical records (EMRs), computerized medical records (CMRs), electronic clinical information systems (ECIS) and computerized patient records (CPRs). Throughout this book, we will use electronic health record (EHR) as the accepted and inclusive term.

Figure 4.1 demonstrates the relationship between EHRs, EMRs and personal health records (PHRs).[8] As indicated in the diagram, PHRs can be part of the EMR/EHR system which may cause confusion.

Figure 4.1: Relationship between EHR, PHR and EMR

The National Alliance for Health Information Technology proposed the following definitions to standardize terms:[9]

Electronic Medical Record: "*An electronic record of health-related information on an individual that can be created, gathered, managed and consulted by authorized clinicians and staff within one healthcare organization.*"

Electronic Health Record: "*An electronic record of health-related information on an individual that conforms to nationally recognized interoperability standards and that can be created, managed and consulted by authorized clinicians and staff across more than one healthcare organization.*"

Personal Health Record: "*An electronic record of health-related information on an individual that conforms to nationally recognized interoperability standards and that can be drawn from multiple sources while being managed, shared and controlled by the individual.*"

ELECTRONIC HEALTH RECORD JUSTIFICATION

Some of the most significant reasons why healthcare systems might benefit from the widespread transition from paper to electronic health records include:

Paper Records Are Significantly Limited

Much of the criticism of handwritten prescriptions can also be applied to handwritten office notes. Figure 4.2 illustrates these problems. Even though the clinician in this example used a paper template, the handwriting is illegible and severely limits the ability of other clinicians (and perhaps the clinician generating the note themselves) to extract and use information from the document. Further, the document cannot be electronically shared or stored. The data elements captured in the note cannot be analyzed using computational tools. Other shortcomings of paper records: they are expensive to copy, transport and store; easy to destroy; difficult to analyze and determine who has seen it; and exert a negative impact on the environment. By contrast, electronic patient encounters are legible, information can be easily viewed, transmitted, and (if stored in structured format) analyzed, and storage of electronic records requires a fraction of the space that paper records demand. Almost every industry, from retail to transportation, or banking, is now computerized and digitized for rapid data retrieval and trend analysis.

THYROID HISTORY AND PHYSICAL
NAME: AGE: DATE:
TX:
C: Improved Stable Worse
1-
2-
3-
4-
HYPER:
PALPITATIONS: TREMORS: ANXIETY: WT LOSS:
HEAT INTOLER: SWEATING: WEAKNESS: HAIR LOSS:
DIARRHEA: INSOMNIA: VISION: RASH:
MENSTRUATION: OTHERS:
HYPO:
FATIGUE: DRY SKIN: COLDNESS: MUSCLE SPAS:
SLEEPINESS: CONSTIPA: VOICE CHAN: WT GAIN:
EDEMA: MENSTRUATION:
NODULE:
DATE FOUND: PAIN: DYSPHAGIA: SOB:
VOICE CHAN: HX OF RADIATION: FHX:
ALL OTHER SYSTEMS: PSFHX REVIEW:
PE: WT: HT: B/P: P: PAIN:
EYES: CONJ: EXOPHT: R L
THYROID:
LYMPH: C: SC: BRUITS:
LUNGS: HEART:
ABD: EXT: PULSE: EDEMA:
NEURO: DTR,S: SKIN:
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US: THY UPSCAN: FNABX: FNABX US
RTO: WKS MOS YR

Figure 4.2: Outpatient paper-based patient encounter form

With the relatively recent healthcare models of patient centered medical home model and accountable care organizations there are new reasons to embrace methods that facilitate data aggregation and reporting, prime amongst them the ability to optimize reimbursement. It is much easier to retrieve and track patient data using EHRs and patient registries than to use labor intensive paper chart reviews. EHRs allow for faster retrieval of lab or x-ray results, and it is likely that EHRs will have an electronic problem summary list that outlines a patient's major illnesses, surgeries, allergies and medications. It is important to note that paper charts are missing during the clinical encounter as much as 25% of the time, according to one study.[10] Even if the chart is available; specific pertinent data elements are missing in 13.6% of patient encounters, according to another study.[11]

Table 4.1 shows the types of missing information and its frequency. According to the President's Information Technology Advisory Committee (PITAC), 20% of laboratory tests are re-ordered because previous studies are not accessible.[12] This statistic has great patient safety, productivity and financial implications.

Table 4.1: Types and frequencies of missing information

Information Missing During Patient Visits	% Visits
Lab results	45%
Letters/dictations	39%
Radiology results	28%
History and physical exams	27%
Pathology results	15%

EHRs allow easy navigation through the entire medical history of a patient. Instead of *pulling paper chart volume 1 of 3* to search for a lab result, it is simply a matter of a few mouse clicks. Another important advantage is the fact that the record is available 24 hours a day, seven days a week and does not require an employee to pull the chart, nor extra space to store it. Adoption of electronic health records has saved money by decreasing full time equivalents (FTEs) associated with ensuring the routine access of patient records, and converting records rooms into more productive space, such as exam rooms. Importantly, electronic health records are accessible to multiple healthcare workers at the same time, at multiple locations. While a billing clerk is looking at the electronic chart, the primary care physician and a specialist can analyze clinical information simultaneously. Moreover, patient information is readily available to physicians on call, so they can review records on patients who are not in their panel. This information may be available off-site; thus, with an EHR a physician can access a patient record from home, instead of having to drive to the office, open the medical records room, and physically search for the patient record.

Furthermore, EHRs improve the level of coding. For example, templates may help remind clinicians to add specific details of the history or physical exam they have performed to justify an appropriate level of coding for the work that they have performed. A study of the impact of an EHR on the completeness of clinical histories in a labor and delivery unit demonstrated improved documentation, compared to prior paper-based histories.[13]

Unlike paper records, EHRs can provide clinical decision support, such as alerts and reminders, which help improve medical decision making. This will be covered later in the chapter.

Another potential advantage of EHRs over paper records is in facilitating clinical research. Not only can the EHR identify eligible patients, it can potentially integrate with research platforms. For example, EHR4CR is a European project involving 35 academic and private partners to create a platform to conduct clinical trials based on EHRs.[14-16]

Need for Improved Efficiency and Productivity

Clinicians want to have patient information available for whenever and wherever they need it. Compared to a paper chart, an EHR allows lab results to be retrieved much more rapidly, thus saving time and money. If lab or x-ray results are frequently missing at the time of the clinical encounter, they are often repeated which adds to this country's staggering healthcare bill. EHRs allow for reduction in duplication of tests; an early study using computerized order entry showed that simply displaying past test results reduced duplication and the cost of future testing by 13%.[17]

EHRs also help to avoid the decrease in efficiency and productivity that occurs due to duplicate prescriptions. It is estimated that 31% of the United States $2.3 trillion-dollar healthcare bill is utilized on administrative tasks.[18] EHRs help to reduce redundant administrative paperwork; for example, they can interface with a billing program that submits claims electronically. Communicating lab results to a patient in the days of paper records often involved a cumbersome communication procedure, but with an EHR, lab results can be forwarded via secure messaging or made available to the patient for viewing via a portal.

Electronic health records can help with efficiency of documentation by utilizing templates and pre-defined macros that generate text. Templates can import relevant data, such as pertinent lab tests, directly into the note. Point-and-click models of navigation, and the use of drop-down menus can reduce documentation time. Of course, one unintended consequence of automating a significant component of patient notes is the introduction of boilerplate language into the clinical record, which adds unneeded text into clinical notes, hindering comprehension.

Embedded clinical decision support is another feature of a comprehensive EHR. Clinical practice guidelines, disease or condition registries, linked educational content and patient handouts can be part of the EHR. This may permit finding the answer to a medical question while the patient is still in the exam room or assist in medical decision making at the point of care.

Clinician workflows can be streamlined by aggregating multiple functions into a single area of the EHR; for example, a physician may be able to sign multiple patient encounters in a single screen of the EHR rather than having to go into each patient chart one by one to sign their note.

EHR dashboards allow clinicians to quickly get a sense of where they stand – not only with parameters of efficiency and productivity (for example a dashboard that displays the number of patients seen each day) but also with patient outcome-related parameters (for example a dashboard that displays to the clinician the degree of control that the diabetic patients in their panel have achieved in comparison to their clinician peers).

However, it should be noted that although EHRs appear to improve overall office productivity, they commonly increase the work of clinicians, particularly with regards to data entry. This will be discussed further in the Loss of Productivity section.

Quality of Care and Patient Safety

As has been previously suggested, an EHR can improve patient safety through multiple mechanisms: (1) Improved legibility of clinical notes, (2) Improved access anytime and anywhere, (3) Reduced duplication, (4) Reminders and clinical alerts (for example a reminder that announces if relevant tests or preventive services are overdue), (5) Clinical decision support that reminds clinicians about drug-drug interactions, known medication allergies, cost and correct dosage of drugs, etc., (6) Electronic problem summary lists (PSLs) provide diagnoses, allergies and surgeries at a glance. Despite the before mentioned benefits, some studies, such as the one by Garrido, have examined quality process measures before and after EHR implementation and failed to show improvement.[19]

To date there has only been one study published that suggested use of an EHR decreased mortality. This EHR had a disease management module designed specifically for renal dialysis patients that could provide more specific medical guidelines and better data mining to potentially improve medical care. The study suggested that mortality was lower compared to a pre-implementation period and compared to a national renal dialysis registry.[20]

It is likely that we are only starting to see the impact of EHRs on quality. Based on internal data Kaiser Permanente determined that the drug Vioxx had an increased risk of cardiovascular events before that information was widely disseminated.[21] Similarly, within 90 minutes of learning of the withdrawal of Vioxx from the market, the Cleveland Clinic queried its EHR to see which patients were on the drug. Within seven hours they deactivated prescriptions and notified clinicians via e-mail.[22] Compare this to the process if paper records were in place – how tedious would it be to go through each patient's paper chart looking to see if Vioxx was included in their medication list, or if patients were noted to be taking the medication in clinical notes. Clearly, electronic clinical quality measure (eCQM) reports are far easier to generate with an EHR compared to a paper chart that requires a chart review. Quality reports can also be generated from a data warehouse or health information organization (HIO) that receives data from an EHR and other sources.[23] Quality reports are the backbone for healthcare reform which will be discussed further in other chapters.

Patient Expectations

The general public has a favorable view of the EHR - according to a Harris Interactive Poll for the Wall Street Journal Online, 55% of adults thought an EHR would decrease medical errors; 60% thought an EHR would reduce healthcare costs and 54% thought that the use of an EHR would influence their decision about selecting a personal physician.[24] The Center for Health Information Technology can make a reasonable case that EHR adoption results in better customer satisfaction through fewer lost charts, faster refills and improved delivery of patient educational material.[25] Patient portals that are part of EHRs are likely to be a source of patient satisfaction as they allow patients access to their records with multiple other functionalities such as online appointing, secure messaging, medication renewals, etc.

Governmental Expectations

EHRs are considered by the federal government to be transformational and integral to healthcare reform. As a result, EHR reimbursement was a major focal point of the HITECH Act. It was the goal of the US Government to have an interoperable electronic health record by 2014. In addition to federal government support, states and payers have utilized initiatives to encourage EHR adoption. CMS is acutely aware of the potential benefits of EHRs to help coordinate and improve disease management in older patients.

Financial Savings

The Center for Information Technology Leadership (CITL) early on suggested that ambulatory EHRs would save $44 billion yearly and eliminate more than $10 in rejected claims per patient per outpatient visit. It should be noted that this optimistic financial projection assumed widespread EHR adoption, health information exchange, interoperability and minor changes in workflow.[26] Several of these processes have not come to fruition.

However, some of the conclusions of this organizations continue to retain their validity. A reasonably articulate case can be made for EHR-related cost savings from eliminated chart rooms and record clerks; as well as a reduction in the need for transcriptionists with the advent of point-and-click templating and voice recognition software, and electronic prescribing has indeed led to fewer callbacks from pharmacists requiring help to decipher physician handwriting. The labor costs of chart pulls are reduced with EHRs, thus saving full time equivalents (FTEs).

Some of the financial savings associated with EHR use are also generated from optimal encounter coding and the increased ability to capture otherwise lost charges. More efficient patient encounters translate to tighter schedules where more patients can be seen each day. Improved savings to payers from medication management are possible with reminders to use generic medications in contrast to more expensive options. EHRs also allow the effective administration of preferred medication lists.

It is not known if EHR adoption will decrease malpractice, hence saving physician and hospital costs. A survey by the Medical Records Institute of 115 practices involving 27 specialties showed that 20% of malpractice carriers offered a discount for having an EHR in place. However, medicolegal risks may be increased during implementation of EHRs – there is an increased risk of errors during the "*implementation chasm*" as clinicians transition from one system to another.[27] These risks include documentation and training gaps, and issues due to software "bugs" and failures. Further, as systems mature the use of email messaging, copy-and-paste models of documentation, and information overload could increase risk.[28] Of course, the presence of EHRs may also be helpful to clinicians – for example, in one study of physicians who had a malpractice case in which documentation was based on an EHR, 55% said the EHR was helpful.[29]

Technological Advances

The time for EHRs is now. The Internet and World Wide Web make the application service provider (ASP) concept for an electronic health record possible. An ASP option means that the EHR software and patient data reside on a remote web server that can be remotely accessed. Computer speed, memory and bandwidth have advanced such that digital imaging is also a reality, so digital image data can be part of an EHR system. Wireless and mobile technologies permit untethered access to the hospital information system and the electronic health record. The unfolding story of the EHR is closely tied to advances in technology that make EHR-related innovations possible.

Need for Integrated and Aggregated Data

Paper health records are standalone, lacking the ability to integrate with other paper forms or information. The ability to integrate health records with a variety of other services and information and to share the information is critical to the future of healthcare reform. Digital healthcare information can be integrated with multiple internal and external applications:

- Integrate with health information organizations (HIOs)
- Integrate with analytical software for data mining to examine optimal treatments, etc. For example, Beth Israel Deaconess Care Organization plans to launch a cloud-based analytics platform that will potentially offer real time population health analytics on EHR based data.[30]
- Integrate genomic data with the electronic health record. Many organizations have begun this journey. There is more information in the chapter on bioinformatics[31]
- Integrate with local, state and federal government information systems for quality reporting and public health issues
- Integrate with algorithms and artificial intelligence. Researchers from the Mayo Clinic could extract Charlson Comorbidity determinations from EHRs, using natural language processing, instead of conducting manual chart reviews.[32]
- Integrate with personal devices, such as activity monitors, glucose monitors, etc.

EHR as a Transformational Tool

It is widely agreed that US Healthcare needs reform in multiple areas. Widespread EHR adoption is a critical part of implementing, maintaining and optimizing a modern healthcare infrastructure. Large organizations such as the Veterans Health Administration and Kaiser Permanente use robust EHRs (VistA and Epic) that generate a significant amount of data for analysis and change the practice of medicine. The integration of data analytics with care has resulted in the improvement in standardization of care, care coordination and population health for these and other similar organizations. In addition, they have begun the process of collecting genomic information for future linking to their electronic records.[33-34]

Need for Coordinated Care

According to a Gallup poll it is very common for older patients to have more than one physician: no physician (3%), one physician (16%), two physicians (26%), three physicians (23%), four physicians (15%), five physicians (6%) and six or more physicians (11%).[35]

Having more than one physician mandates good communication between the primary care physician, the specialist and the patient. This becomes even more of an issue when different healthcare systems are involved. O'Malley et al. surveyed 12 medical practices and found that in-office coordination was improved by EHRs, but the technology was not mature enough to improve coordination of care with external physicians.[36] Electronic health records are being integrated with health information organizations (HIOs) so that inpatient and outpatient patient-related information can be accessed and shared, thus improving communication between disparate healthcare entities. Home monitoring (telehomecare) can transmit patient data from home to an office's EHR also assisting in the coordination of care. We will point out in a later section that coordination of care across multiple medical transitions is part of Meaningful Use.

Figure 4.3 shows the early perceptions of physicians regarding EHR benefits in a 2011 National Center for Health Statistics (NCHS) survey.[37]

NATIONAL ACADEMY OF MEDICINE'S VISION FOR EHRS

The history and significance of the National Academy of Medicine (NAM) (previously known as the Institute of Medicine) is detailed in chapter 1. They have published multiple books and monographs on the direction US

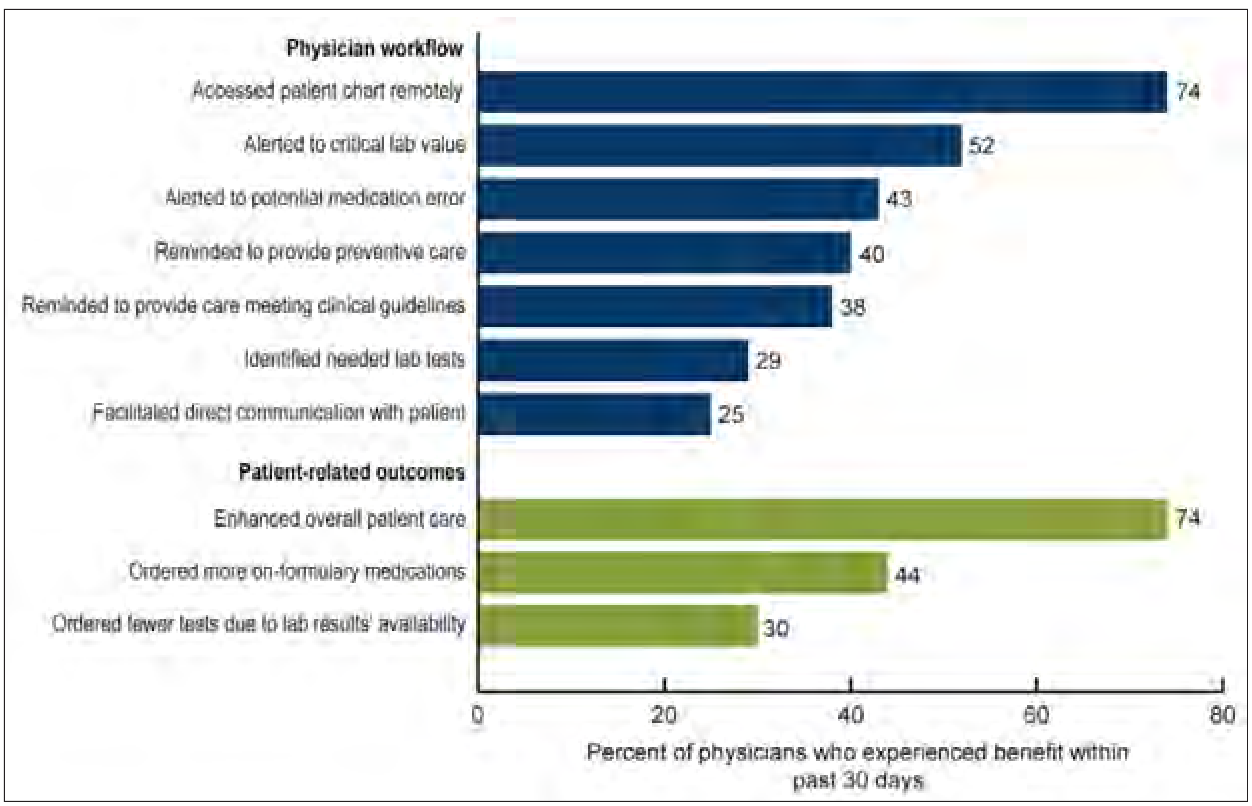

Figure 4.3: Physician's perceptions of EHR benefits

Medicine should take, including *The Computer-Based Patient Record: An Essential Technology for Health Care*. This visionary work was originally published in 1991 and was revised in 1997 and 2000.[6] In this book and their most recent work *Key Capabilities of an Electronic Health Record System: Letter Report* (2003) they outline eight core functions all EHRs should have:

- Health information and data: For the medical profession to make evidence-based decisions, you need a lot of accurate data and this is accomplished much better with EHRs than paper charts; *if you can't measure it, you can't manage it.*
- Result management: Physicians should not have to search for lab, x-ray and consult results. Quick access saves time and money and prevents redundancy and improves care coordination.
- Order management: CPOE should reduce order errors from illegibility for medications, lab tests and ancillary services and standardize care.
- Decision support: Should improve overall medical care quality by providing alerts and reminders.
- Electronic communication and connectivity: Communication among disparate partners is essential and should include all tools such as secure messaging, text messaging, web portals, health information exchange, etc.
- Patient support: Recognizes the growing role of the Internet for patient education as well as home telemonitoring.
- Administrative processes and reporting: Electronic scheduling, electronic claims submission, eligibility verification, automated drug recall messages, automated identification of patients for research and artificial intelligence can speed administrative processes.
- Reporting and population health: We need to move from paper-based reporting of immunization status and biosurveillance data to an electronic format to improve speed and accuracy.[38]

ELECTRONIC HEALTH RECORD KEY COMPONENTS

Many current EHRs have more functionality than the eight core functions recommended by NAM/IOM and this will increase over time. The following components are desirable in any EHR system. One of the advantages of certification for Meaningful Use is that it helped standardize what features were important. The following are features found in most commercial EHRs available currently:

- Clinical decision support systems (CDSS) to include alerts, reminders and clinical practice guidelines. CDSS is associated with computerized physician order entry (CPOE). This will be discussed in more detail in this chapter and the patient safety chapter.
- Secure messaging (e-mail or text messaging) for communication between patients and office staff and among office staff. EHRs will likely include messaging that is part of the Direct Project, explained in the chapter on health information exchange. Telephone triage capability is important.
- Practice management software, scheduling software and patient portals that are embedded or connect with an interface. This feature will handle billing and benefits determination and discussed further in another section.
- Managed care module for physician and site profiling. This includes the ability to track Health plan Employer Data and Information Set (HEDIS) or similar measurements and basic cost analyses
- Referral management feature
- Retrieval of lab and x-ray reports electronically
- Retrieval of prior encounters and medication history
- Computerized Physician Order Entry (CPOE). Primarily used for inpatient order entry but ambulatory CPOE also important. This will be discussed in more detail later in this chapter.
- Electronic patient encounter. One of the most attractive features is the ability to create and store a patient encounter electronically. In seconds, you can view the last encounter and determine what treatment was rendered.
- Multiple ways to input information into the encounter should be available: free text (typing), dictation, voice recognition and templates.
- The ability to input or access information via a smartphone or tablet PC
- Remote access from the office, hospital or home
- Electronic prescribing discussed in a section to follow
- Integration with a picture archiving and communication system (PACS), discussed in a separate chapter
- Knowledge resources for physician and patient, embedded or linked
- Public health reporting and tracking
- Ability to generate electronic clinical quality measures (eCQMs) for reimbursement, discussed in the chapter on quality improvement strategies
- Problem summary list that is customizable and includes the major aspects of care: diagnoses, allergies, surgeries and medications. Also, the ability

to label the problems as acute or chronic, active or inactive. Information should be coded with ICD-10 or SNOMED CT so it is structured data.

- Ability to scan in text or use optical character recognition (OCR)
- Ability to perform evaluation and management (E & M) determination for billing
- Ability to create graphs or flow sheets of lab results or vital signs
- Ability to create electronic patient lists and disease registries.
- Preventive medicine tracking that links to clinical practice guidelines
- Security and privacy compliance with HIPAA standards
- Robust backup systems
- Ability to generate a Continuity of Care Document (CCD) or Continuity of Care Record (CCR), discussed in the data standards chapter
- Support for client server and/or application service provider (ASP) option [39]

The following screen shots reflect the eight basic functions of an EHR as outlined by NAM. Screen shots were derived from the open source EHR LibreHealth.[40]

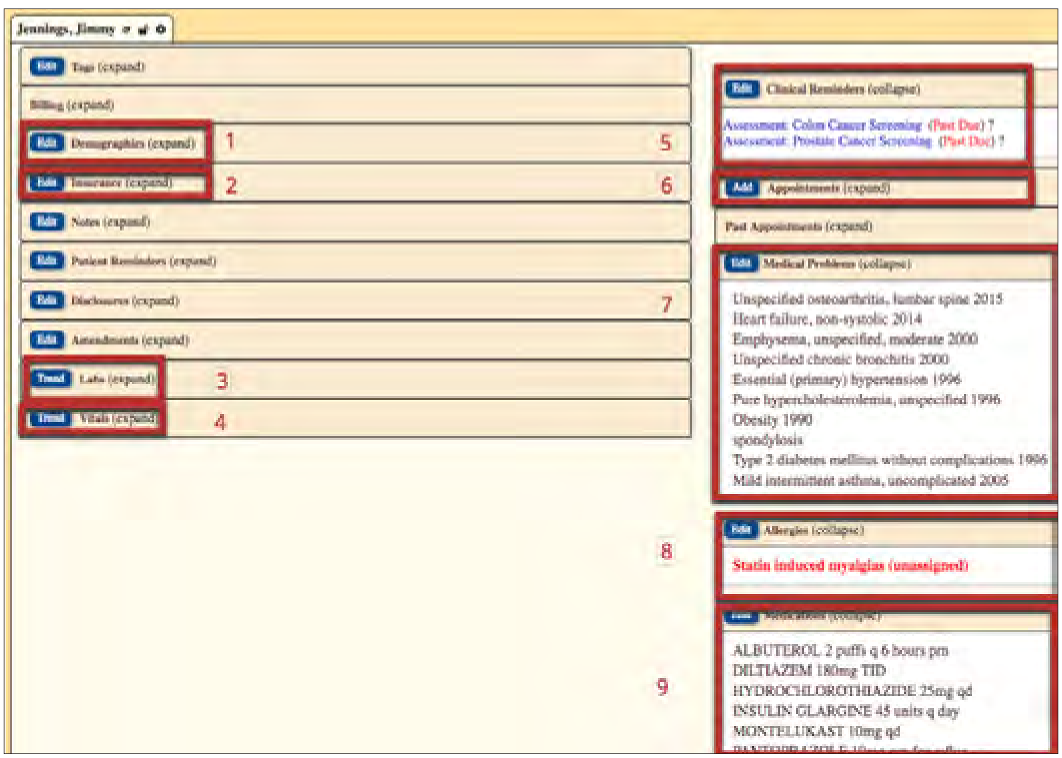

Figure 4.4: Health Information and Data (Problem Summary List)

1. Demographics
2. Insurance information
3. Lab results and graphing capability
4. Vital signs and graphing capability
5. Clinical reminders and alerts
6. Future and past appointments
7. Medical problems
8. Allergies
9. Medications

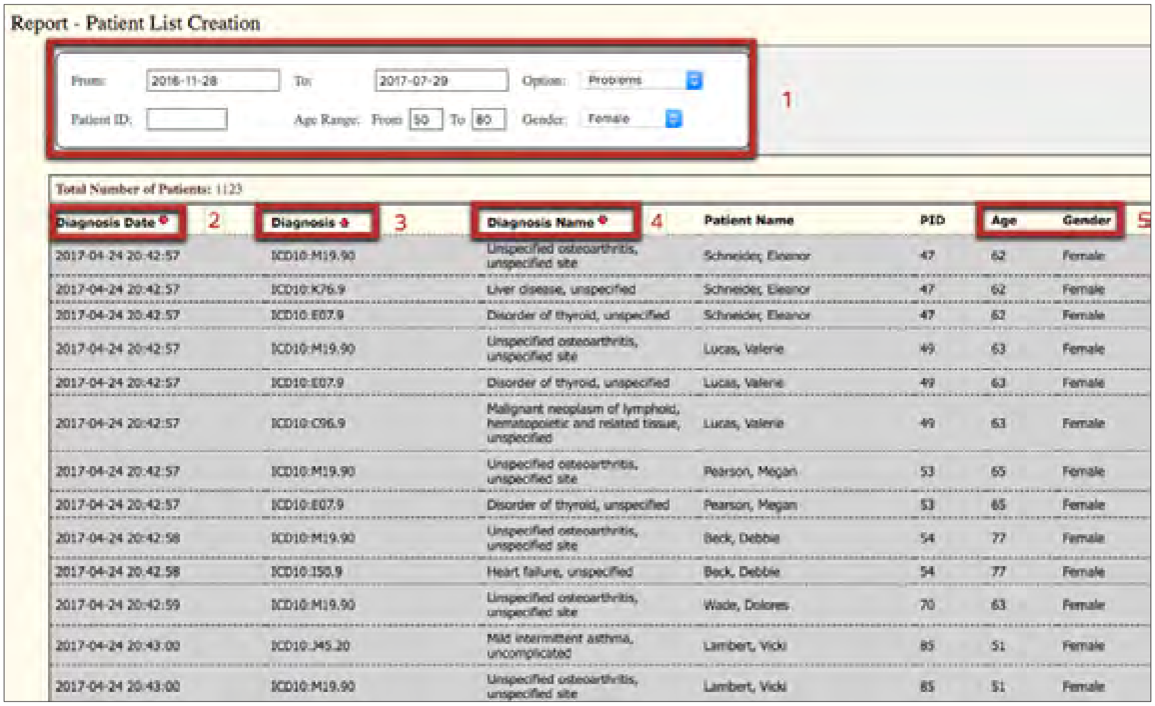

Figure 4.5: Health Information and Data (Patient reports)

1. Search criteria
2. Diagnosis date
3. Diagnosis by ICD-10 code
4. Diagnosis Name
5. Age and Gender

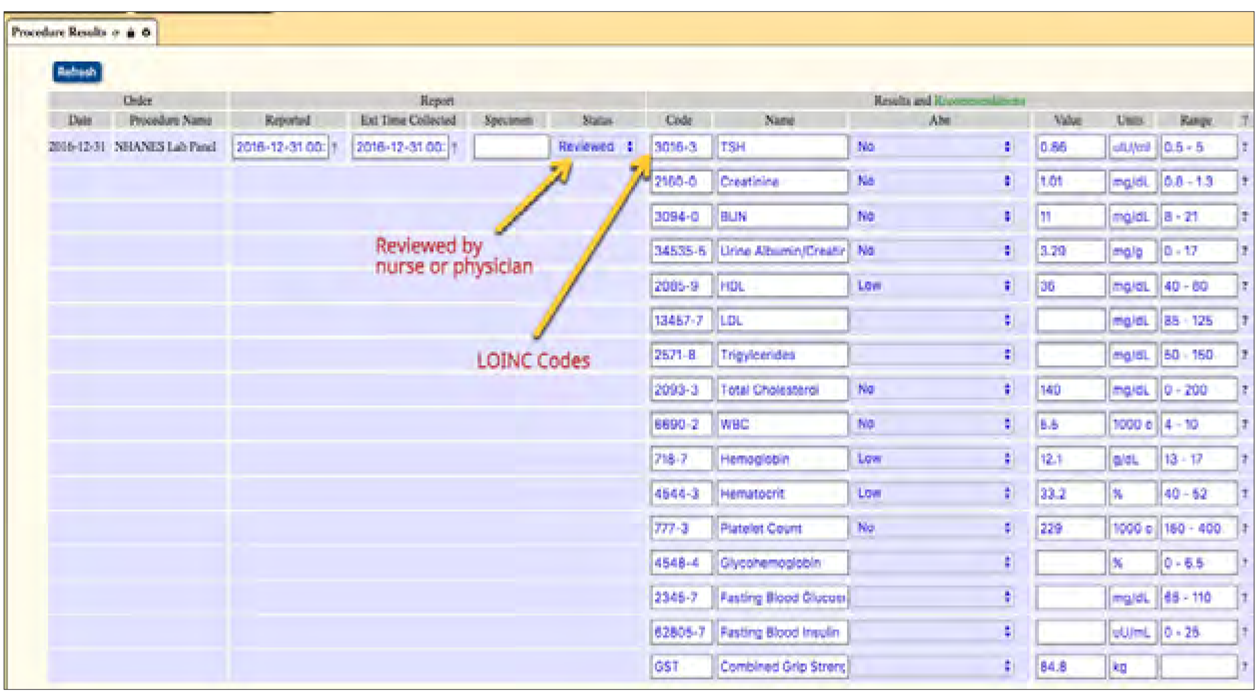

Figure 4.6: Results management (Laboratory results)

Figure 4.7: Order Management (electronic prescription)

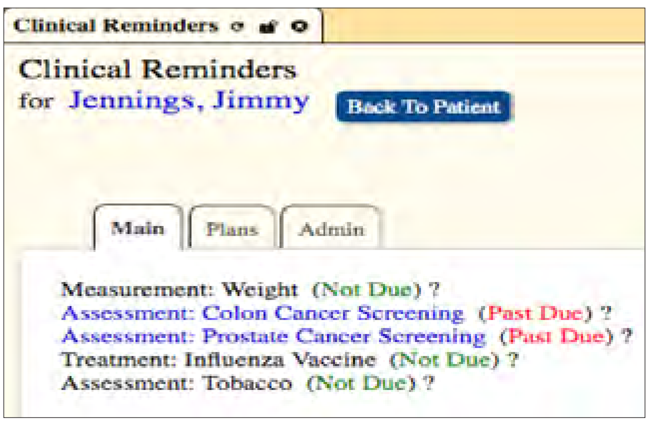

Figure 4. 8: Decision support (alerts and reminders)

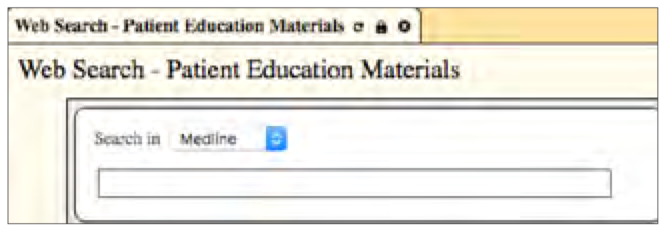

Figure 4.10: Patient Support (Patient Education)

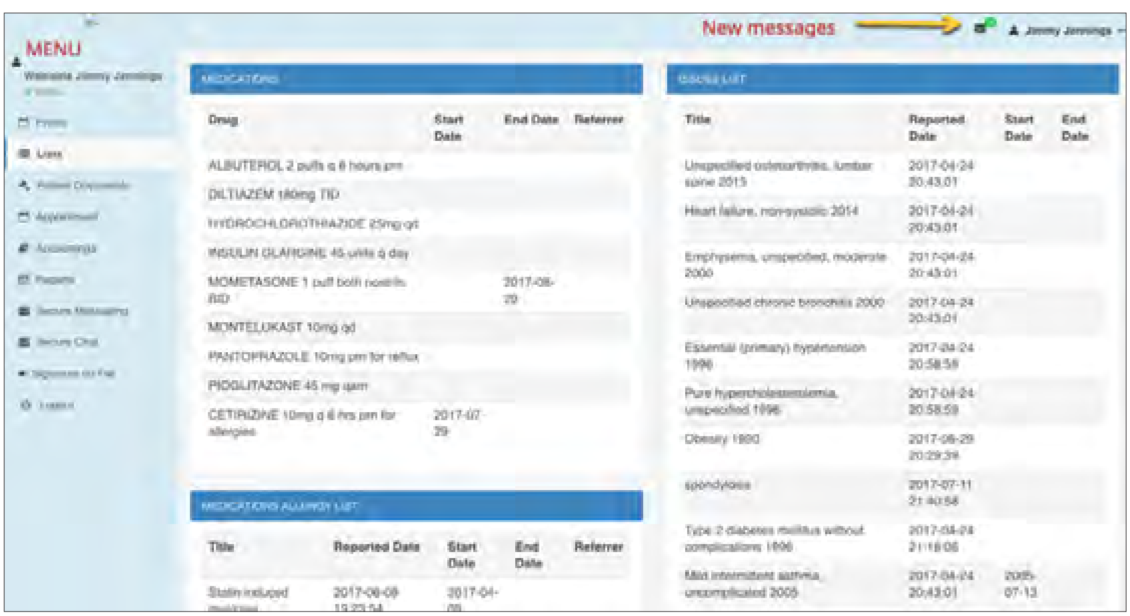

Figure 4.9: Electronic communication (patient portal)

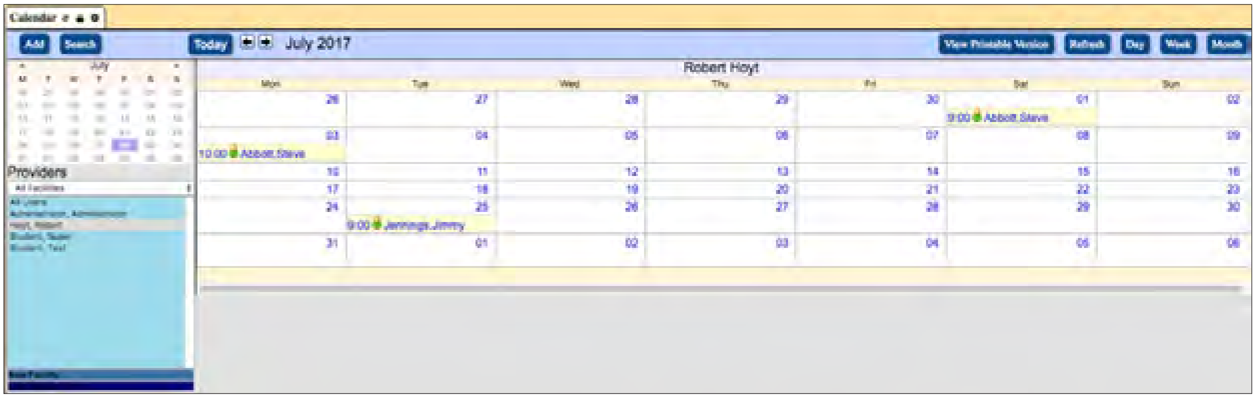

Figure 4.11: Administration (Calendar)

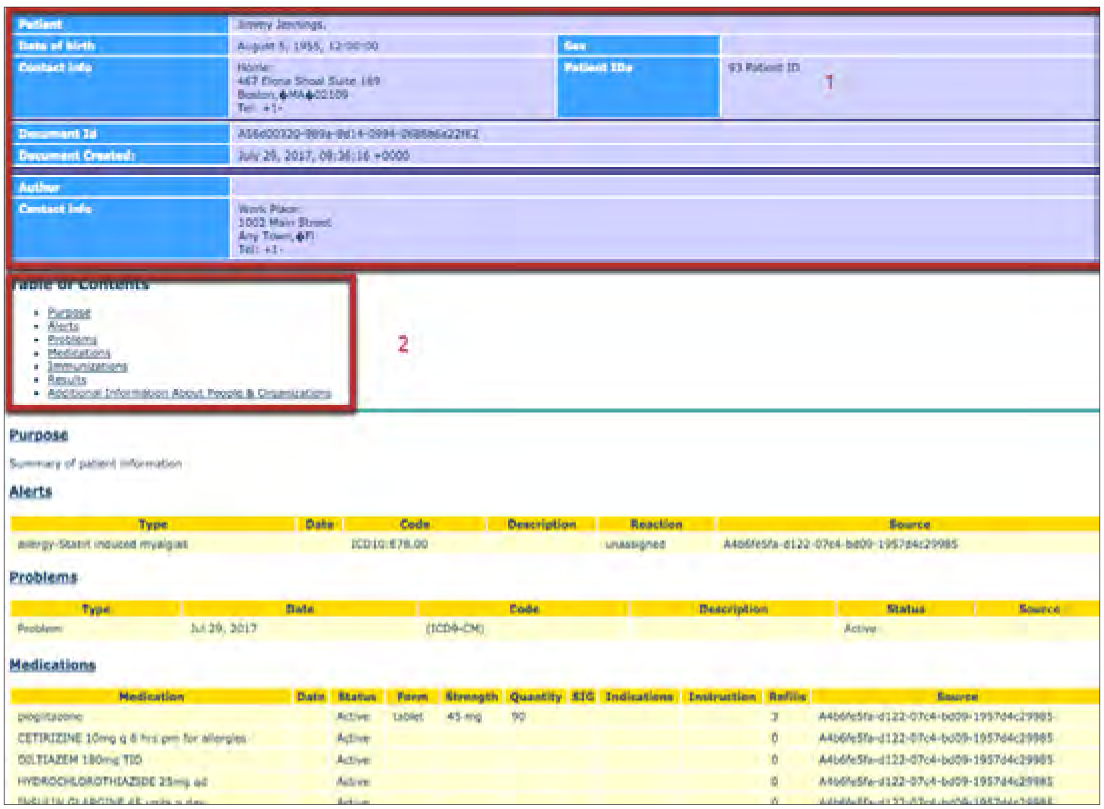

Figure 4.12: Reporting (Continuity of Care Document)

1. Patient demographics and identification
2. Hyperlinked table of contents

COMPUTERIZED PHYSICIAN ORDER ENTRY (CPOE)

CPOE is an EHR feature that processes orders for medications, lab tests, imaging, consults and other diagnostic tests. Many organizations such as the National Academy of Medicine and Leapfrog see CPOE as a powerful instrument of change. However, there is limited evidence that CPOE reduces medication errors, cost and variation of care. This is discussed in the following sections.

Reduce Medication Errors

CPOE has the potential to reduce medication errors through a variety of mechanisms.[41] Because the process is electronic, rules can be embedded that check for allergies, contraindications and other alerts. Koppel et al. note that when compared to paper records, CPOE overcomes the issue of illegibility, is associated with fewer errors associated with ordering drugs with similar names, is more easily integrated with decision support systems than paper, can be easily linked to drug-drug interaction warning, is more likely to identify the prescribing physician, is able to link to adverse drug event (ADE) reporting systems, can avoid medication errors like trailing zeroes, creates data that is available for analysis, can point out treatment and drugs of choice, can reduce under and over-prescribing, and allows prescriptions to reach the pharmacy quicker.[42]

Inpatient CPOE: This functionality was recommended by the NAM as far back as 1991. In 1998, a landmark study by David Bates published in JAMA showed that CPOE can decrease serious inpatient medication errors by a relative risk reduction of 55%. However, this frequently cited article did not show reduction of potential adverse drug events (ADEs).[43] Additionally, many of the studies showing reductions in medication errors using technology were reported by a limited number of academic institutions who had implemented their own home grown EHR and had the infrastructure to allow robust technology support. In contrast, other hospital systems with commercial EHRs were less likely to experience the same optimistic results. A 2008 systematic review of CPOE with CDSS by Wolfstadt et al. only found 10 studies of high quality and those dealt primarily with inpatients. Only half of the studies could show a statistically significant decrease in medication errors, none were randomized and seven were home-grown systems, so results are difficult to generalize.[44]

With the inception of CPOE we are seeing evidence of new errors that result from technology. The term "*e-iatrogenesis*" has been used to describe this phenomenon, the term can be defined as "*patient harm caused at least in part by the application of health information technology*."[45] Others refer to this phenomenon as unintended adverse consequences (UACs). Campbell et al. delineated these unintended consequences as falling within nine types (in order of decreasing frequency): 1) more/new work for clinicians; 2) unfavorable workflow issues; 3) never ending system demands; 4) problems related to paper persistence; 5) untoward changes in communication patterns and practices; 6) negative emotions; 7) generation of new kinds of errors; 8) unexpected changes in the power structure; and 9) overdependence on the technology.[46]

A 2005 article reported that the mortality rate increased 2.8%-6.5% after implementing a well-known EHR.[47] In a 2006 article, also from a children's hospital implementing the same EHR, they found no increase in mortality; perhaps due to better planning and implementation. One of the authors stated that the CPOE system eliminated handwriting errors, improved medication turnaround time and helped standardize care.[48] Nebeker reported on substantial ADEs at a VA hospital following the adoption of CPOE that lacked full decision support, such as medication alerts.[49] On the other hand,, another inpatient study showed a reduction in preventable ADEs (46 vs. 26) and potential ADEs (94 vs. 35) compared to pre-EHR statistics.[50]

A more recent systemic review and meta-analysis suggested that transition from paper-based ordering to commercial CPOE systems in ICUs was associated with an 85% reduction in medication prescribing error rates, but that there was mixed evidence that CPOE reduced ICU mortality. The study concluded "t*here is also a critical need to understand the nature of errors arising post-CPOE and how the addition of advanced CDSSs can be used to provide even greater benefit to delivering safe and effective patient care.*"[51]

Outpatient CPOE: There is more of a chance for a medication error written for outpatients, because there are far more prescriptions written in the ambulatory setting than in acute care facilities. According to an optimistic report by the Center for Information Technology Leadership, adoption of an ambulatory CPOE system (ACPOE) would eliminate about 2.1 million ADEs per year in the USA. This could potentially prevent 1.3 million ADE-related visits, 190,000 hospitalizations and more than 136,000 life-threatening ADEs.[26] However, a systematic review by Eslami was not as optimistic as he concluded that only one of four studies demonstrated reduced ADEs and only three of five studies showed decreased medical costs. Most showed improved guideline compliance, but it took longer to electronically prescribe and there was a high frequency of ignored alerts (alert fatigue).[52] Kuo et al. reported medication errors from primary care settings. The study concluded that 70% of medication errors were related to prescribing and that 57% of errors might have been prevented by electronic prescribing.[53]

Reduce Costs

Several studies have shown reduced length of stay and overall costs in addition to decreased medication costs with the use of CPOE.[54] Tierney was able to show in an early study an average savings of $887 per admission when orders were written using guidelines and reminders, compared to paper-based ordering that was not associated with clinical decision support.[55]

One study by Nuckols et al. suggested that in comparison to paper records, CPOE saved, on average between $11.6 million and $170 million per hospital in mean lifetime savings in 2012 dollars, depending on their size. The study also suggested that quality-adjusted life-years (QALYs) also increased proportionately, and anticipated increases in CPOE implementation from 2009 through 2015 could save $133 billion and 201,000 QALYs nationwide.[56]

Reduce Variation of Care

There is significant potential for CPOE to facilitate the ability of clinicians to reduce variations in care, and studies have reflected this. For example, one study showed excellent compliance by physicians when the drug ordered by them was changed by a decision support algorithm.[57]

On the surface CPOE implementation seems easy: just replace paper orders with an electronic format. The reality is that CPOE represents a significant change in work flow and is not just the adoption of new technology. Any change in workflow requires extensive training to allow end-users to adapt to the new paradigm. With this in mind, it should be noted that many of the studies that extoll the ability of CPOE to reduce variation in the delivery of clinical care were conducted at medical centers with well-established health informatics programs; where the acceptance level of new technology was unusually high. Several of these institutions such as Brigham and Women's Hospital developed their own EHR and CPOE software.

Compare this experience with that of a rural or critical access community hospital implementing CPOE for the first time with potentially inadequate IT, financial and leadership support. It is likely that smaller and more rural hospitals and ambulatory care offices will have a steep learning curve.

Adoption of CPOE was initially slow, partly because of associated costs and partly because workflow changes were extensive – the process of computerized input is significantly more cumbersome and often slower than scribbling orders on a paper cahrt.[58] Physician resistance to change was on the forefront of implementers minds at the onset of deployment of CPOE; early unsuccessful implementations such as the one in Cedars-Sinai Medical Center in California gave clinical informaticians pause for thought.

Over time, CPOE has become palatable to most physicians. One reason is that the functionality is now well-established in clinical workflows; personnel that used to exclusively exist to enter physician orders, such as inpatient unit secretaries, now no longer perform the task of entering orders. Another reason is that house staff, and not attendings, write most orders in teaching hospitals and academic medical centers, and as a consequence of being the "*EHR generation*" of physicians they do not know any other way to enter orders other than CPOE.

Even though CPOE is in widespread use, it does require forethought, leadership, planning, training and the use of physician champions to implement successfully.

CLINICAL DECISION SUPPORT SYSTEMS (CDSS)

Clinical decision support may be defined as "*any electronic or non-electronic system designed to aid directly in clinical decision making, in which characteristics of individual patients are used to generate patient-specific assessments or recommendations that are then presented to clinicians for consideration.*"[59]

However, clinical decision support is not just an alert or notification. Table 4.2 outlines some of the clinical decision support available today. Calculators, knowledge bases and differential diagnoses programs, which primarily originated as standalone programs, are increasingly being integrated into modern EHR systems.

Table 4.2: Clinical decision support

Type of CDSS	Examples
Knowledge	UpToDate, DynamedPlus
Calculators	eCalcs
Trending/Patient tracking	Flow sheets, graphs
Medications	CPOE and drug alerts
Order sets/protocols	CPGs and order sets
Reminders	Mammogram due
Differential diagnosis	DxPlain
Radiology CDSS	ACR Select
Laboratory CDSS	What lab tests to order
Public health alerts	Infection disease alerts, SMART apps

Sheridan and Thompson have discussed various levels of CDSS: (level 1) all decisions by humans, (level 2) computer offers many alternatives, (level 3) computer restricts alternatives, (level 4) computer offers only one alternative, (level 5) computer executes the alternative if the human approves, (level 6) human has a time line before computer executes, (level 7) computer executes automatically, then notifies human, (level 8) computer informs human only if requested, (level 9) computer informs human but is up to computer and (level 10) computer makes all decisions.[60] Most EHR systems may offer alternatives and provide reminders but make no decisions on their own. With artificial intelligence and natural language processing becoming more sophisticated, this could change in the future.

A majority of studies in the informatics literature regarding CDSSs have been sourced from four institutions – the Veterans Administration (VA), Brigham and Women's Hospital and associated Partners Healthcare, the Regenstrief Institute, and Intermountain Healthcare. These institutions did not use commercial EHRs for most of their history and the CDSS literature reflects this. (Ironically, many of the institutions with early home grown EHRs have transitioned to large commercial EHRs). But, despite this significant limitation, there is some evidence that both commercial as well as home-grown CDSSs improve process measures across a variety of settings.[61] But evidence that suggests improvements in clinical outcomes, efficiency measures and even the case for financial ROI remains less definitive.

There have been some attempts to study why certain types of CDSS succeed while others fail. Roshanov et al. identified several factors that could partially explain this phenomenon. Their paper concluded that success of CDSSs was likely to be greater when they provided advice concurrently to clinicians and patients, or when practitioners were required to provide reasons when over-riding CDSS advice than for systems that did not.[62] On the other hand, CDSSs that presented decision support within electronic charting or order entry systems was associated with a higher likelihood of failure.

No treatise on CDSSs is complete without mentioning the well-cited "Ten Commandment" paper by Bates et al. that delineated the ten principles of effective clinical decision support. This paper specifically references the speed of the CDSS, the need for CDSS to anticipate clinician needs and deliver in real time, and the ability of the CDSS to fit into the user's workflow. The "commandments" also include some pithy observations: that usability matters, that physicians strongly resist suggestions not to carry out an action in the absence of an alternative, instead preferring to change direction rather than stop, and that simple interventions are often more effective than complex guidelines. Bates et al. also note that CDSSs need to ask the end-user for additional information when it is necessary, that CDSS implementers should monitor the impact of their interventions, and that knowledge-based systems should be maintained and curated appropriately.[63]

Knowledge support. Numerous digital knowledge-based resources are being integrated with EHRs. For example, UpToDate[64] has been embedded into several EHRs, and diagnostic (ICD-10) codes can be hyperlinked to further information or you can use *infobuttons*. Infobuttons are a HL7 standard and commonly used to link to important information.[65] Other products such as Dynamed Plus, are available as *infobuttons*, web services API, search box widget, or embedded links.[66]

Calculators. Calculators are now embedded into most commercial EHRs, particularly in the medication and lab ordering sections. Important clinical calculations, such as calculations that assist appropriate antibiotic dosing based on kidney function (creatinine clearance) as well as scoring patient risks such as the 10-year cardiovascular risk, can now be achieved at the point of care.

Flow sheets, graphs and other visual representation of patient data. The ability to view graphic representations of patient data, such as results and vital signs, allows clinicians to visualize data and track trends in a manner that assists in cognitive clinical reasoning.

Medication ordering support. CDSSs help clinicians detect known allergies, identify potential drug-drug interactions, as well as avoid prescribing excessive or ineffective dosages of medications. These interventions have obvious potential in decreasing medication errors and improve patient safety.

Reminders. Computerized reminders that are part of the EHR assist in tracking the yearly preventive health screening measures, such as mammograms. Shea et al. performed a meta-analysis and concluded that there was clear benefit for vaccinations, breast cancer and colorectal screening.[67] A well-designed system should allow for some customization of the reminders as national recommendations change over time. However, it should be noted that reminders are not always heeded by busy clinicians who may choose to ignore them.

Order sets and practice guidelines. Order sets are groups of pre-established related orders that are related to a symptom or diagnosis. For instance, with just a few mouse clicks a provider may place an order set for pneumonia that might include the antibiotic of choice, supplemental oxygen, an order for a chest x-ray, etc.; thus the clinician's workflow is rendered more efficient. Order sets can also reflect best practices (clinical practice guidelines), thus offering optimal patient care.

Differential Diagnosis generators. Dxplain is a differential diagnosis program developed at Massachusetts General Hospital. When the patient's symptoms are entered, it generates a differential diagnosis (a list of stratified diagnostic possibilities). The program has been in development since 1984 and is currently web-based.

A licensing fee is required to use this program. As of 2018 it cannot be integrated into an EHR.[68] In spite of the potential benefit, an extensive 2005 review of CDSSs revealed that only 40% of the 10 diagnostic systems studied showed benefit, in terms of improved clinician performance.[69] Liebovitz offers suggestions as to how future EHRs could improve diagnoses.[70] Artificial intelligence continues to improve so it is likely that EHRs will have the ability to assist with differential diagnosis in the future.

Radiology CDSS. Physicians, particularly those in training, may order imaging studies that are either incorrect or unnecessary. For that reason, several institutions have implemented clinical decision support to improve imaging study ordering. Appropriateness criteria have been established by the American College of Radiologists. Massachusetts General Hospital has had radiology order entry since 2001; a study showed a decline in low utility imaging study orders from 6% down to 2% and this decrease was attributed to the use of decision support.[71]

Beginning on January 1, 2018, the Protecting Access to Medicare Act (PAMA) will require referring clinicians to access and understand appropriate use criteria (AUC) prior to ordering certain diagnostic imaging services: CT, MRI, nuclear medicine exams and PET scans for Medicare patients. These criteria can be standalone or integrated into the EHR. The American College of Radiology has developed the CDSS, known as ACR Select.[72]

Laboratory CDSS. It should be no surprise that clinicians occasionally order inappropriate lab tests, for a variety of reasons. A Dutch study of primary care demonstrated that 20% fewer lab tests were ordered when clinicians were alerted to lab clinical guidelines.[73] Another study showed a decrease in duplicate test ordering when laboratory CDSSs were available.74

Public Health Alerts. The New York Department of Health and Mental Hygiene used Epic EHR's "*Best Practice Advisory*" to alert New York physicians about several infectious disease issues. The EHR-based alert also hyperlinked to disease specific order sets for educational tips, lab and medication orders.[75] A newer approach to public health clinical decision support has been to use web services and the new data standard FHIR, discussed in the next section and the chapter on data standards.[76]

Smart apps. Like smartphone apps, new applications were developed that link within the EHR to add more functionality. Fast healthcare interoperability resources (FHIR) is a relatively new HL7 standard that utilizes open standards such as RESTFul APIs. That means, they can communicate with any EHR that has open APIs. Apps can be created in a short period of time for clinical care, public health and research. The SMART App Gallery includes dozens of apps, as of 2018. More apps are described on the HL7 web site.[77-78]

More information about clinical decision support can be found in the chapter on clinical decision support systems and these references.[63, 79-82]

ELECTRONIC PATIENT REGISTRIES

Unlike EHRs that focus on individual patients, registries focus on populations. Patient registries are defined as "*an organized system that uses observational study methods to collect uniform data (clinical and other) to evaluate specified outcomes for a population defined by a particular disease, condition, or exposure, and that serves one or more predetermined scientific, clinical, or policy purposes*."[83]

Modern registries tend to fall into the following categories:

- Chronic disease management: for example, a diabetic educator might have all patients with type 2 diabetes in a registry for management purposes.
- Research registries: if a healthcare system has all e.g. total hip replacement patients in a single registry they can evaluate and compare different outcomes with different prostheses, etc.
- Safety registries: reporting to e.g. the FDA
- Public health registries: reporting immunizations, cancer and biosurveillance
- Quality registries: an option to report performance data to e.g. CMS[84]

Therefore, registries perform multiple functions, to include:

- Natural history of disease: following patients over time is important for both clinicians and researchers to better understand disease progression
- Effectiveness: treatments are better evaluated with larger patient populations, something that would be difficult with a single EHR or clinic
- Safety: studying larger patient populations in a registry is likely to be more valid than a small population
- Quality: to meet value-based reimbursement programs, clinicians will have the option to upload patient results to a registry with batch reports to e.g. CMS

Registry functions are very consistent with the IOM's vision of a "*learning healthcare system*" where treatment is based on constant analysis of patient data to generate the most current and best evidence.

Historically, early patient registries were paper-based, followed by electronic spreadsheets, followed by electronic standalone registries and finally electronic registries integrated with electronic health records. While many electronic health records permit creation of patient lists, most to do not have comprehensive registries with embedded clinical practice guidelines. If not integrated with an EHR, a HIO or a web-based registry, the inputting of patient information would have to be manual, which is not efficient. To create interoperability between EHR and registry there must be syntactic and semantic interoperability discussed in the chapter on health information exchange and this reference.[84]

An interesting recent initiative is the Guideline Advantage, a collaborative program between the American Heart Association, American Cancer Society and the American Diabetes Association. With EHR connectivity, practices can submit performance measures covering heart disease, diabetes and cancer to this qualified clinical data registry (QCDR) that will forward the data to CMS, as part of quality reporting. Participants can view data at the individual, physician and practice level, as well as benchmark their results against national averages.[85]

There is some evidence that the use of registries results in improved care. For example, Han et al. was able to show that patients with type 2 diabetes were more likely to have appropriate laboratory tests done and retinal exams compared to those not in a registry. In addition, patients in a registry were less likely to be admitted or be seen in an emergency room.[86]

PRACTICE MANAGEMENT INTEGRATION

Most medical offices have had computerized practice management (PM) systems for many years, regardless of whether they utilized paper or electronic health records, or a hybrid of these two. While there are many reasons why PM systems have become so prevalent, one primary driving force has been the ability of practice management systems to generate more rapid claims submission and adjudication. Without an electronic system, time and money would be lost on faxes, phone calls and snail mail. The American Medical Association estimated that inefficient claims submission systems lead to about $210 billion annually in unnecessary costs.[87] A PM system is designed to capture all the data from a patient encounter necessary to obtain reimbursement for the services provided. This data is then used to:

- Generate claims to seek reimbursement from healthcare payers
- Apply payments and denials
- Generate patient statements for any balance that is the patient's responsibility
- Generate business correspondence
- Build databases for practice and referring physicians, payers, patient demographics and patient encounter transactions (i.e., date, diagnosis codes, procedure codes, amount charged, amount paid, date paid, billing messages, place and type of service codes, etc.)

Additionally, a PM system provides routine and ad hoc reports so that an administrator can analyze the trends for a given practice and implement performance improvement strategies based on the findings. For example, a medical office administrator can use the PM system to compare different payers with regards to the amount reimbursed for each given service or the turnaround time between claims submission and payment. The results lead to deciding which managed care plans the practice will participate in versus those plans that the practice may want to consider not accepting in the future. Another example is to analyze all payers for a given service performed in the practice to determine if that service is a good use of the practice's clinical time. This analysis provides one aspect of whether the practice should consider continuing to offer a certain service such as case management of a patient who is receiving home health services through an agency. Of course, the administrator must weigh services that aren't profitable against any negative impact on overall patient satisfaction, but the PM system provides a means of analyzing payment performance.

Most PM systems also offer patient scheduling software that further increases the efficiency of the business aspects of a medical practice. Finally, some PM systems offer an encoder to assist the coder in selecting and sequencing the correct diagnosis (International Classification of Diseases, Current revision, clinically modified for use in the United States, or ICD-10-CM) and procedure (Current Procedural Terminology, fourth edition or CPT-4® and Healthcare Common Procedure Coding System or HCPCS) codes. Even when a physician determines the appropriate codes using a *superbill*, (a list of the common codes used in that practice along with the amount charged for each procedure), there are times when a diagnosis or procedure is not listed on the superbill and an encoder makes it efficient to do a search based on the main terms and select the best code. Furthermore, some encoders are packaged with tools such as a subscription to a newsletter published by the American Medical Association (AMA) known as "CPT® Assistant" that help the practice comply with correct coding initiatives which in turn optimize the reimbursement to which the practice is legally and ethically entitled and avoids fraud or abuse fines for improper coding.

Clinical and Administrative Workflow in a Medical Office

Several steps are common to almost any medical practice with regards to treating patients and getting reimbursed properly for the services provided. The steps are subdivided based on whether the patient has been to this practice previously for any type of service. The first step is to get the patient registered. This can be accomplished via a practice website or by the patient calling the office to schedule an appointment. Figure 4.13 demonstrates typical outpatient office workflow.

ELECTRONIC HEALTH RECORD ADOPTION

Outpatient (Ambulatory) EHR Adoption

In 2006, the adoption rate of ambulatory EHRs was reported to be in the 10% to 20% range.[93] The most recent National Ambulatory Medical Care Survey (2015) reported that 86% of office-based respondents had an EHR; 54% with a basic system and 78% with a certified system. The percentage varied by state from a low of 66% to a high of 90%.[88]

Adoption of an EHR does not necessarily indicate that the end-user is using the advanced capabilities of an EHR, as indicated in Table 4.3 from HIMSS Analytics. The results indicate that very few hospital systems have achieved an advanced level of EHR sophistication.[89]

Table 4.3: HIMSS Analytics EMR Adoption Model 4th quarter 2017

Stage	Capabilities	Ambulatory EHR	Inpatient EHR
7	Complete EMR, data analytics to improve care	10.8%	6.4%
6	Documentation templates, full CDSS, closed loop medication administration	21.8%	33.8%
5	Full R-PACS	8.6%	32.9%
4	CPOE, clinical decision support (clinical protocols)	0.8%	10.2%
3	Clinical documentation, CDSS (error checking)	9.4%	12.0%
2	CDR, controlled medical vocabulary, CDS, HIE capable	16.5%	1.8%
1	Ancillaries installed: lab, rad, pharmacy	30.5%	1.5%
0	Ancillaries not installed	1.9%	1.4%

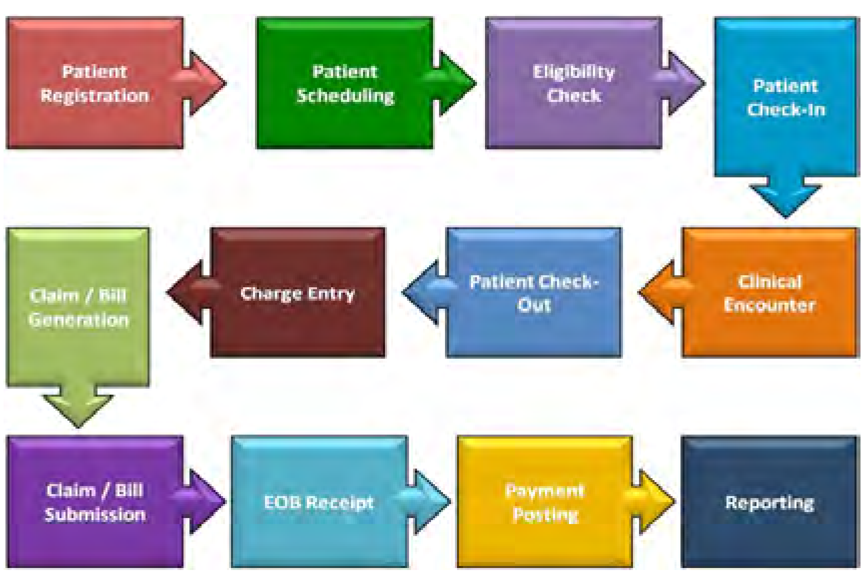

Figure 4.13: Typical Outpatient office workflow (EOB = explanation of benefits)

Inpatient EHR Adoption

The Office of the National Coordinator reported that adoption of a certified inpatient EHR by non-federal acute care hospitals had risen from 72% in 2009 to 96% in 2015 (the most current data).[90]

As anticipated, EHR adoption by rural or small non-teaching hospitals continues to be lower than by larger, urban hospitals and academic medical centers.[91]

International EHR Adoption

Until about a decade ago, the US lagged behind many other developed countries in its adoption of EHRs.[92] A 2009 study showed that the US continued to lag in EHR adoption among primary care physicians in developed countries.[93] A 2015 Organization for Economic Cooperation and Development report on 38 countries stated that "*all but 2 pilot countries reported use by at least half of primary care physicians and many had rates above 75%*."[94]

However, other countries have had their share of implementation failures. As described in the chapter on International Health Informatics, in 2011 the United Kingdom had to dismantle their $17 billion health IT project, the NHS National Programme for IT (NPfIT).[95]

ELECTRONIC HEALTH RECORD CHALLENGES

Many of the same barriers to HIT adoption discussed in Chapter 1 also pertain to EHR adoption and use.

Financial Barriers

Although there are models that suggest significant savings after the implementation of ambulatory EHRs, the reality is that ambulatory EHRs are expensive to implement, particularly for smaller or solo practices. Multiple surveys report that lack of funding is the number one barrier to EHR adoption.[96] In a 2005 study published in *Health Affairs*, initial EHR costs averaged $44,000 (range $14-$63,000) per FTE (full time equivalent) and ongoing annual costs of $8,500 per FTE. These costs included the purchase of new hardware, etc. Financial benefits averaged about $33,000 per FTE provider per year. Importantly, more than half of the benefit derived was from improved coding.[97] This is not a surprise given the fact that studies have shown that physicians often *under-code* for fear of punishment or lack of understanding what it takes to code to a certain level.[98] A 2008 survey reported about one-third of physicians paid between $500-$3,000 per clinician, one-third paid between $3,001-$6,000 and about one-third paid more than $6,000 per clinician for their EHR.[99]

A 2011 study reported on the financial and nonfinancial costs of implementing a commercial EHR in a healthcare network in Texas. They calculated that implementation for a five-physician primary care practice would be about $162,000 with $85,500 in maintenance expenses in the first year. They also estimated that the average end-user would require 134 hours to train and prepare for implementation.[100] Another study reported on 5-year return on investment from 49 practices that were part of the Massachusetts eHealth Collaborative, before and after EHR implementation. The study was prior to CMS reimbursement under the HITECH Act but was similar in that the eHealth Collaborative paid for most costs related to purchase and implementation. They found only 27 percent of practices would achieve a positive five-year return and that a majority would experience a loss. The average projected loss over five years was $43,473 per physician. There were striking differences between the winners and losers of EHR adoption.[101] Eastaugh sampled 62 hospitals and was impressed that most overestimated the ability of EHRs to improve efficiency. The EHR/HIT expenses were 4.3-8.1% of total revenue and 22-39% of available capital. He supports hospitals calculating the total cost of ownership (TCO) to achieve a more realistic appraisal of actual EHR cost.[102]

It is important to consider that integration with other disparate systems such as practice management systems can be very expensive and hard to factor into a cost-benefit analysis. The web-based application service provider (ASP) option is less expensive in the short term and perhaps in the long term, when you factor in the expenses to maintain and upgrade an office client-server network. According to many studies EHR adoption was far higher in large physician practices that could afford the initial high cost.[103]

Physician Resistance

Next to EHR reimbursement lack of support by medical staff was consistently the second most commonly perceived obstacle to adoption.[104] Physicians have to be shown that a new technology is good for their patients, and not just a tool to save time or make money. Often these benefits are hard to prove, especially because EHR implementation will not fix old work flow issues and indeed require clinicians to significantly alter the way they deliver patient care. Change also requires buy-in from all stakeholders, not just from management or a few early adopters.

Loss of Productivity

It is likely physicians will have to work at reduced capacity for several months with gradual improvement depending on training, aptitude, etc. This is a period when physician champions can help maintain morale and momentum with a positive attitude. According to one systematic review CPOE used on central station desktops for CPOE was not time efficient; the weighted average relative time difference across these studies reported an increase in documentation time of 238.4%.[105]

A study of Internal Medicine physicians published in 2014, reported that attending physicians lost about 48 minutes of free time per clinic day, compared to 18 minutes lost per day for trainees.[106] A time motion study of 57 physicians in 4 specialties concluded "*for every hour physicians provide direct clinical face time to patients, nearly 2 additional hours is spent on EHR and desk work within the clinic day*."[107]

Loss of productivity is, in part, due to the change in workflow discussed in the next section.

Work Flow Changes

EHR end users, and indeed all clinicians delivering patient care, will have to change workflows when an EHR is implemented – changes in documentation, the way that patient information is routed between clinicians and ancillary staff, changes in communication patterns both between clinicians and with the patient, new procedures and policy for electronic data privacy and security, even changes in the workflow of how clinical information is handed off to on-call colleagues, consultants and inpatient providers. If these changes to clinical work flows are not anticipated, post-implementation dissatisfaction may increase alarmingly. Work flow analysis will also determine optimal alterations to work flows to ensure uninterrupted and efficient patient care after implementation.

Reduced Physician-Patient Interaction

The addition of the computer in the exam room has heralded a paradigm shift in clinician-patient communication. No longer are clinicians able to maintain eye contact with the patient as often as they did during the days of paper – now clinicians need to divide their time between the patient and the EHR screen, often to the detriment of the patient. Careful attention to workstation placement and ergonomics may mitigate some of these issues, for example the use of a tablet PC may help diminish the time the clinician spends not looking at the patient. The overall effect of exam room technology also depends on the skill of the physician integrating the technology appropriately when they are with the patient at the point of care.[108-110]

Because CPOE and encounter documentation takes longer to complete (on average) compared to paper processes, there is a valid concern that attending physicians or housestaff will be forced to spend more time documenting on the computer and less time with the patient. A study reported in 2013 showed that interns spent only 12% of their time in direct patient-related care, but 40% on the computer.[111] A second report in 2013 reported that emergency room physicians spent 28% of their time in direct patient care but 43% of time with data entry. On average, the total number of mouse clicks for a 10 hour shift approached 4,000.[112] These findings further strain the already negative perception of many patients that they don't have enough face time with their physician.

Usability Issues

Usability has been defined as the "*effectiveness, efficiency and satisfaction with which specific users can achieve a specific set of tasks in a particular environment*."[113]

Ratwani et al. studied the user-centered design of 11 EHR vendors and concluded that there was great variability in usability.[114] A 2017 systematic review by Ellsworth et al identified 120 articles that discussed EHR usability and determined that there was a paucity of quality published studies, as well as a lack of a standard formal means to evaluate usability.[115]

The American Medical Informatics Association (AMIA) board has made a set of recommendations to enhance patient safety and quality of care by improving the usability of EHRs:

- Recommendations for the academic informatics community includes emphasizing usability and human factors research by prioritizing standard use cases, developing a core set of measures specific to adverse events related to health IT use, research and promote best practices for safe EHR implementation
- Policy recommendations include standardizing EHR systems and ensuring interoperability, establishing an adverse event reporting system for health IT, and developing an educational campaign for safe and effective EHR use
- Specific recommendations for EHR vendors include developing a common user interface style guide for certain EHR features, and performing formal usability assessments on their products

- Recommendations for end users suggests adopting best practices for EHR system implementation and ongoing maintenance, and monitoring how IT systems are used with the goal of reporting IT-related adverse events.[116]

Another issue is that commercial EHRs are typically never delivered to healthcare organization as out-of-the-box turnkey installations. Organizations adapt the product to their needs, and the production environment may be somewhat different than the vendor's test environment. Wright et al. recommends testing EHRs in the production environment to mimic how they are used by clinicians. This will allow unintended behavior to be more readily apparent before patient harm can occur.[117]

Integration Issues

Integrating clinical information system elements can be challenging. Best-of-breed solutions require close attention to integration of individual components, and even commercial EHR products require integration with existing software, or with external connections that are required to continue business as usual. Interoperability with other EHRs, registries, health information networks, and data warehouse may also need to be considered. Needless to say, integration can be expensive.

Ultimately, genomic information will also be extensively integrated with most EHRs. Already, several large healthcare systems have begun the journey by linking genotypical information with phenotypical information in the EHR. As pointed out by Hazin et al. and discussed further in the chapter on bioinformatics, there are a host of ethical, legal and social implications and challenges associated with this integration.[118] We are a long way away from having the physician and patient utilize genomic information in any comprehensive manner, and lack clinical decision support to alert patients and providers of significant genomic risk. Additionally, both clinicians and patients may not appreciate the complexity associated with interpreting genomic data. Evidence of this was found in a 2010 survey by CAHG that reported that 90% of physicians polled thought that genomics-based medicine would influence healthcare by "some" to "great extent" but only 8% claimed to be very familiar with genomic medicine and only 16% stated they had training in this area in medical school.[119]

Quality Reporting Issues

EHRs have the potential to generate a variety of data necessary for compliance with meaningful use objectives, to include quality reports. Quality reports have been tied to physician reimbursement in several situations, however, obstacles associated with linking physician compensation to the quality of care they provide remain. In early 2013, two reports from Weill-Cornell Medical College in New York City highlighted issues with quality measure reporting. In one study the accuracy of automated EHR data reporting was low, compared to manual chart review. In another study that examined quality reporting in the Primary Care Information Project in New York it was noted that within the first two years of using an EHR there was no improvement in overall quality, even with high levels of technical assistance.[120-121]

Lack of Interoperability

Data standards are necessary for interoperability, and reimbursement for Meaningful Use mandates that EHRs demonstrate the ability to exchange information. Although we have numerous standards already accepted (discussed in Chapter 5) they will likely need to be updated and new standards added based on use cases. Perhaps the most interesting standard with interoperability ramifications is the HL7 standard known as Fast Healthcare Interoperability Resources (FHIR). A variety of resources have been created to handle common healthcare use cases. FHIR resources are structured data in the form of XML or JSON objects. Each resource has a unique URL. Lab results and other data could be called up using RESTful APIs.[77] Some of the major EHR vendors are already actively involved with this standard. FHIR is discussed further in Chapter 5.

Furthermore, computers are based on data and not information, as discussed in the chapter on healthcare data, information and knowledge.

Privacy Concerns

The HITECH Act of 2009 introduced a new certification process for EHRs sponsored by ONC, in addition to CCHIT certification. This new certification ensures that EHRs will be able to support Meaningful Use and that they also will be HIPAA compliant. ONC certification includes requirements on database encryption, encryption of transmitted data, authentication, data integrity, audit logs, automatic log off, emergency access, access control and accounting of HIPAA releases of information. The HITECH Act also strengthened the prior HIPAA requirements as they relate to EHRs, particularly in the areas of enforcement of HIPAA and notification of breaches. Both civil and criminal penalties for Business Associates (as well as covered entities) were introduced. Civil penalties in their harshest form can range up to 1.5 million dollars. If a data breach of PHI (protected health information) occurs, all affected individuals must be notified. If more than 500 individuals are affected, HHS must be notified as well. Sale of PHI is prohibited.[131] Users of EHRs must:

- Use HIPAA compliant technology
- Provide physical and software security of data systems
- Provide physical and software security of their network(s) including mobile and remote computing
- Provide access control with defined user roles, passwords and user authentication and auditing
- Monitor and manage user behavior
- Have written security policies and procedures
- Have an effective disaster recovery plan[122]

EHRs pose new potential privacy and security threats for patient data, but with proper technology as well as proper health entity and user behavior, these risks can be mitigated. On the bright side, EHRs offer new safeguards unavailable in the paper record world, like audit trails, user authentication, and back-up copies of records. Further details are available in the chapter on privacy and security.

Legal Aspects

A 2010 *Health Affairs* article estimated that malpractice costs in the US are around $55 billion dollars annually (in 2008 dollars) or 2.4% of what we spend on health care.[123] Will EHRs increase or decrease that number? Unfortunately, there is no definitive answer. Most studies suggesting lower malpractice claims after EHR implementation are not designed to prove cause and effect and may not be generalizable to other practices or regions.[124] Arguments can be made for either outcome. On one hand, by increasing the quality of care, theoretically EHRs should reduce malpractice risk. Yet this conclusion assumes that quality and malpractice are related in a linear fashion, which may well not be the case. On the other hand, EHRs that are poorly designed, or that contain bugs, could promote new errors. This risk also points to a need for monitoring and reporting EHR-generated errors with the intention of taking corrective action to avoid "e-iatrogenesis." The Office of the National Coordinator (ONC) for Health IT understands that a system of monitoring and corrective action for EHR-related errors needs to be implemented and outlined its plans in a December 2010 statement.[125]

Two important areas of potential risks and benefits include clinical documentation and clinical decision support. One might expect that the more comprehensive documentation produced by EHRs will improve a physician's defense against malpractice. It certainly may. However the automated way that EHRs carry information forward from one note to the next can also promote errors, for example if a piece of data is recorded incorrectly from the start, yet never corrected.[126] E-discovery laws now allow electronically stored data related to patient records to be considered discoverable for the purpose of malpractice, so the metadata and audit trails that supplement EHR documentation can be used both to defend and to impeach a physician in a malpractice case.[127] Decision support alerts and guidelines embedded into EHRs could potentially provide a defense against malpractice claims if their advice is followed. But what if alerts or guidelines are overridden? There may be very appropriate reasons to do so, but will physicians be expected to document the reason for each and every alert they override? Will they run the risk of being penalized if they don't?

Improved access to information provided by health information exchanges (HIEs) should improve the coordination of care, the quality of medical information that is available, and thus the quality of medical decision making. But, will clinicians overlook key nuggets of clinical information simply because they are overwhelmed by the volume of information they receive? Will ready access to outside information on a patient make a physician more liable if he or she doesn't always actively search for every piece of potentially relevant information? In addition, user errors can arise as users climb a steep learning curve to become proficient with EHRs. Care needs to be taken particularly during the implementation of an EHR to guard against user error.

Finally, as EHRs become the standard of care, will practicing without an EHR become a medicolegal liability? At this point in time it is still undetermined whether EHRs will significantly impact the incidence and expense of malpractice in a positive or a negative way.[128]

Inadequate Proof of Benefit

Successful implementation of HIT at a medical center with a long-standing history of systemic IT support does not necessarily translate to another healthcare organization with less IT support and infrastructure. A systematic review by Chaudry is often cited as proof of the benefits of HIT, but in his conclusion, he states "*four benchmark institutions have demonstrated the efficacy of health information technologies in improving quality and efficiency. Whether and how other institutions can achieve similar benefits and at what costs, are unclear*."[129]

There have been several articles that failed to demonstrate a significant impact of EHRs on medical quality in the US and in Europe.[130-134] A more positive study was published in 2011 of more than 25,000 diabetics in 46 practices that showed achievement of diabetic care was significantly better for practices with EHRs, compared to paper-based practices. They measured intermediate outcomes and not actual patient outcomes, so we don't know the impact on morbidity or mortality.[135] Three additional observational articles measured intermediate outcomes, such as hemoglobin A1c levels, but only one study showed significant benefit.[136-138] A study comparing New York primary care physicians with and without EHRs showed a statistically higher score on nine quality measurement in those clinicians who used an EHR.[139] Another article compared quality measures in those physicians who attested for MU, compared to those who did not and found that MU was associated with marginally better results in 2 measures, worse results for 2 measures and no difference in 3 measures.[140]

A systematic review published in 2012 that looked at the economics of HIT and medication management could find little evidence that CPOE or CDSS were cost effective. Importantly, they noted that the quality of the literature was heterogonous and of poor quality.[141] Another systematic review evaluated the impact of point-of-care computer reminders, as part of CPOE/CDSS on physician behavior and found a very small positive effect. Specifically, the review found that the reminders improved adherence to care by a median of only 4.2%.[142] There has also been a hope and perception that having prior test results readily available in the EHR would reduce testing duplication. In a large retrospective study of before and after EHR implementation, having access to electronic results of lab and imaging results resulted in increased, rather than decreased ordering.[143]

Patient Safety, Reliability, EHRs and Unintended Consequences

Patient Safety. Unfortunately, with implementation of most technologies new problems and issues arise that were not considered initially. EHRs are no exception to this observation and a variety of unintended consequences have been reported. Weiner coined the term *e-iatrogenesis* to mean "*patient harm caused at least in part by the application of health information technology*."[154] Several studies have shown increased errors after implementing CPOE.[45, 49, 126, 144-146] Campbell et al. outlined nine examples of unintended consequences related to CPOE implementation:

1. *"More work for clinicians*
2. *Unfavorable workflow changes*
3. *Never ending demands for system changes*
4. *Conflicts between electronic and paper-based systems*
5. *Unfavorable changes in communication patterns and practices*
6. *Negative user emotions*
7. *Generation of new kinds of errors*
8. *Unexpected and unintended changes in institutional power structure*
9. *Overdependence on technology"*[147]

Alert fatigue is another common unintended consequence related to CPOE, discussed in more detail in the chapter on patient safety.

The US federal government is keenly aware of the unintended consequences associated with HIT and EHRs after reports by the Joint Commission and the Institute of Medicine.[148-149] Furthermore, the Pennsylvania Patient Safety Authority published a report on errors related to use of default values in 2013. They reported that wrong-time, wrong-dose, inappropriate auto-stops and wrong-route errors were often related to default values that should have been changed.[150]

In response to concerns AHRQ released the monograph *Guide to Reducing Unintended Consequences of Electronic Health Records* in 2011. This Guide discusses unanticipated and undesirable consequences of EHR implementation.[151] In mid-2013, ONC released the report HIT Patient Safety and Surveillance Plan. The plan will make EHR error reporting easier, to include allowing the EHR to generate the report to patient safety organizations (PSOs).[152]

ONC developed a series of EHR risk assessment tools known as Safety Assurance Factors for EHR Resilience (SAFER) guides. The series includes 9 guides covering EHR risk areas, such as system interfaces, system configuration and patient identification. The guides are available on the ONC web site.[153]

Reliability. In spite of successful EHR implementations, we have also seen dramatic failures in 2013, with EHR shutdowns from 1 to 10 days.[154-155] Healthcare organizations must develop backup plans to include temporarily relying on paper-based processes until the EHR is re-established.

With better training or re-design some of the technology-related errors are likely to be overcome. More research is needed to obtain a balanced opinion of the impact of EHRs on quality of care, patient safety and productivity. Furthermore, we will need to study the impact on all healthcare workers and not just physicians.

THE HITECH ACT AND MEANINGFUL USE

Arguably, the most significant EHR-related initiative occurred in 2009 as part of the American Recovery and Reinvestment Act (ARRA). Two major parts of ARRA, Title IV and Title XIII are known as the Health Information Technology for Economic and Clinical Health or HITECH Act.

For clinicians to participate in this program they had to: (1) be eligible, (2) register for reimbursement, (3) use a certified EHR, (4) demonstrate Meaningful Use (MU), and (5) receive reimbursement.

Eligible Professionals (EPs)

Medicare: Medicare defined EPs as doctors of medicine or osteopathy, doctors of dental surgery or dental medicine, doctors of podiatric medicine, doctors of optometry and chiropractors. Hospital-based physicians such as pathologists and emergency room physicians are not eligible for reimbursement. Hospital-based is defined as providing 90% or more of care in a hospital setting. The exception is if more than 50% of a physician's total patient encounters in a six-month period occur in a federally qualified health center or rural health clinic. Physicians may select reimbursement by Medicare or Medicaid, but not both. They cannot receive Medicare EHR reimbursement and federal reimbursement for e-prescribing. They can receive Medicare reimbursement as well as participate in the Physicians Quality Reporting System (PQRs). If they participate in the Medicaid EHR incentive program they can participate in all three programs.

Medicaid: Medicaid EPs are defined as physicians, nurse practitioners, certified nurse midwives, dentists and physician assistants (physician assistants must provide services in a federally qualified health center or rural health clinic that is led by a physician assistant). Medicaid physicians must have at least 30% Medicaid volume (20% for pediatricians). If a clinician practices in a federally qualified health center (FQHC) or rural health clinic (RHC), 30% of patients must be *needy individuals*. The Medicaid program is administered by the states and physicians can receive a one-time incentive payment for 85% of the allowable purchase and implementation cost of a certified EHR in the first year, even before Meaningful use is demonstrated. Medicaid is also different from Medicare in the following: payment over six years does not have to be consecutive and there are no penalties for non-participation.[156]

Registration: Registration began in January 2011. Medicare physicians had to have a National Provider Identifier (NPI) and be enrolled in the CMS Provider Enrollment, Chain and Ownership System (PECOS) and National Plan and Provider Enumeration System (NPPES) to participate.[156]

Certified EHRs: An EHR had to be certified by a recognized certifying organization for a physician or hospital to receive reimbursement. As of mid-2017, there were four organizations that provide certification.[157] Standards and certification criteria are listed, as are the currently certified EHRs. Users can view ambulatory and inpatient EHR categories and search by product name. The search should review who certified the EHR, whether it was for a complete or modular EHR and the EHR certification ID number they would need for reimbursement. The newest 2014 EHR certification is for stage 2 meaningful use.[158]

Meaningful Use (MU): The goals of MU are the same as the national goals for HIT: (a) improve quality, safety, efficiency and reduce health disparities; (b) engage patients and families; (c) improve care coordination; (d) ensure adequate privacy and security of personal health information; (e) improve population and public health. Three processes stressed by ARRA to accomplish this are: e-prescribing, health information exchange and the production of quality reports. Meaningful Use consists of three stages: stage 1 would begin the basic process of data capturing and sharing; stage 2 would require advanced data processes and sharing and stage 3 would aim at improving patient outcomes.

- Stage 1: Meaningful Use mandated a *core set* and a *menu set* of objectives. Participants needed to meet 15 core objectives and five out of 10 menu objectives. They also needed to choose at least one population and public health measure. For each objective, there were reporting measures that must be met to prove Meaningful use. Once a clinician completed two years of MU under stage 1, they moved on to stage 2.[156]
- Stage 2: to align stages 1 and 2, CMS released a modification of MU criteria in October 2015 that gave guidance for the future. 2016 was the last year EPs could enroll in the Medicare MU program. In 2017 EPs attested to new criteria under the Quality Payment Program.[156]
- Stage 3: Medicaid physicians and eligible hospitals will follow new Stage 3 guidelines. EPs would have 10 objectives and eligible hospitals 9 objectives. EHRs must be certified by either 2014 or 2015 guidelines. The reporting period for 2017 was a minimum of any continuous 90-days during the year. The changes to specific Medicaid objectives for 2017 are posted on the CMS web site.[159]

Stage 3 was intended to be implemented in 2018, but instead Medicare providers will transition to Quality Payment Program (QPP) that is part of the Medicare Access and CHIP Reauthorization Act (MACRA). This program offers 2 tracks for medical practices. The first track is the Merit-based Incentive Payment System (MIPS). Clinicians need to report up to 6 quality, 4 improvement and 9 advancing care information measures, for a minimum of 90 days. The quality category replaces PQRS, the improvement activities are new and the advancing care information replaces the Medicare MU program. The second track is the Advanced Alternate Payment Model, which provides more reimbursement (5%) but involves some financial risk. The MU program will change names to Advancing Care Information (ACI) and a new Quality Payment Program (QPP) would be based on value, not volume. For the ACI program there are two routes to submit performance data. One involves 15 measures and the other 11 measures. Details are available on the QPP web site.[160] MACRA will be discussed in multiple chapters but is likely to change over time.

ONC's Health IT Dashboard posts visualizations about most key aspects of meaningful use and health IT. CMS posts information about meaningful use payments. As of December 2017, CMS paid EPs $24.8 billion through the Medicare program and $12.5 billion through the Medicaid program.[156]

THE IMPACT OF THE MEANINGFUL USE PROGRAM

There is little evidence to suggest that meaningful use programs have improved patient outcomes, as opposed to patient processes. In other words, clinicians may be reporting hemoglobin A1c results more often on their patients with diabetes but does that translate into fewer myocardial infarctions or amputatons? While Stage 3 meaningful use and MIPS attempts to be more outcome based, the reality is that the retrospective reporting of processes continues.

In an interesting 2017 article by Goroll entitled "*Emerging from from EHR Purgatory – Moving from Process to Outcomes*" the author posits that EHRs have beome a billing platform where adequate documentation and coding skill is mandatory, yet there is low physician and patient satisfaction with the process.[161] Perhaps with Alternate Payment Models (APMs), the second payment model under MACRA/MPP, they will result in a prospective payment model with more attention to outcomes and less on processes. CMS Innovation Center launched such a program called Comprehensive Primary Care Plus (CPC+) in 2017 with 2866 primary care practices involved. Participants will focus on improving access, continuity and population health.[162] Payment details include:

- **Care Management Fee:** participants will be paid a per-beneficiary-per month (PBPM). The payment is risk-adjusted and paid on a quarterly basis.
- **Performance-Based Incentive Payment:** CPC+ will prospectively also pay based on patient experience measures, clinical quality measures, and utilization measures related to cost
- **Payment under the Medicare Physician Fee Schedule:** Track 1 will continue to bill and receive payment from Medicare fee-for-service (FFS). Track 2 will also continue to bill, but the FFS payment will be reduced to account for CMS shifting part of the FFS payments into CPC+ payments

LOGICAL STEPS TO SELECTING AND IMPLEMENTING AN EHR

EHR implementations are complex affairs. They are not simply IT projects. They are practice transformation projects that should be considered socio-technical-economic initiatives. If EHRs are approached as simply software to be installed and clinicians are similarly approached as users to be trained in using the software, an EHR implementation will undoubtedly falter or even fail. Thus, health care organizations involved in implementing an EHR are wise to plan their process carefully, with attention to the following questions:

- Why are we doing this?
- Who should be involved?
- How will this impact end-users and how do we prepare them?
- What will be the major barriers?
- What should we start doing now to overcome identified barriers?
- Are we ready for change?
- How will the change be managed?

Implementation of an EHR can be divided into three separate, yet intertwined phases: Pre-implementation, implementation and post-implementation.[163] While each phase is distinct, the success of subsequent phases depends upon the thorough planning and execution of the prior stages.

Pre-implementation begins with deciding whether to purchase an EHR (it is rare for a health care organization to create one themselves these days) and ends with signing a contract with a vendor for a specific EHR. This requires a thorough understanding not only of the organization's needs and current state but also of the selected software's abilities and limitations. The main activity in pre-implementation is choosing the EHR that will be used, but several steps that might be done during implementation, such as workflow mapping, may be done and some say should be done, during pre-implementation. Workflow mapping involves a detailed step-by-step description, typically utilizing a flowchart of how a process is accomplished. For example, how are notes created or how are patient messages handled or how are prescription refills managed?[164]

Implementation of the EHR starts with the signing of the contract and ends with the go-live date. Experts in IT implementations often categorize facets of implementation into People, Process, or Technology issues.[165] Alternatively, they can be termed: *Team, Tactics and Technology*.

Issues related to people are particularly important in an EHR implementation. Unless the people issues are managed well from the start, later adoption of the varied functionality inherent in an EHR will likely suffer. Key people issues include leadership, change management, goal establishment and expectation setting. An implementation will have three key types of leaders: a project manager, a senior administrative sponsor, and a clinical champion. The clinical champion will invariably be a physician, but hospital settings will typically have a nurse champion as well. The need for a project manager, someone knowledgeable and experienced in managing a complex IT project with overlapping timelines and multiple stakeholders, is obvious. Senior leadership sponsorship and support is also essential, because an EHR implementation will affect nearly all aspects of a hospital or clinic's operations and thus consistent support from the organization's leader or leaders will be required as inevitable bumps in the road are encountered.

Some healthcare organizations have learned the hard way that implementing an EHR without one or more physician champions can be disastrous. When it comes to clinical matters, physicians rely on other physicians. Because an EHR affects clinical practice in so many ways, respected, supportive, influential clinicians are needed to encourage other physicians to accept and utilize the system effectively.[166]

In inpatient settings, a nurse or clinical champion is essential to ensure that decisions made incorporate all disciplines within the facility. When implementing an EHR it is important to view operations from all perspectives (e.g. physicians, nurses, medical assistants, pharmacists, other support personnel and administrators). Without a nurse champion, decisions made might be solely physician-focused. Additionally, nurses commonly drive the change process in hospitals. Commitment to success, engagement of everyone, and a shared interest in improvement is paramount, so attitude is everything.[167]

Because of the degree of change involved in implementing an EHR for the first time, change management skills are needed. This topic is beyond the scope of this book, but many good resources can be found on it. One good introductory and classic resource is Kotter's book *Leading Change*.[168] An important part of change management is setting goals and establishing expectations.

Many specific process (or tactical) decisions are determined during implementation. How will we use the EHR to redesign our workflows? What is our data entry strategy? Which data will we enter discretely, which will we scan and which (if any) will we leave out of the EHR? Who will do this data entry and when? What order sets will we create? What other information systems will the EHR connect to and what kind of interfaces will it require? Will we follow a *big bang* (all personnel/sites and EHR functions at once) or a phased implementation approach (certain user groups and/or certain sites/departments and or certain EHR functions in sequential order)? How will we conduct user training? What will we do about note templates? How much customization will we allow? How will we utilize super-users be utilized? EHR software does vary in its complexity.

Small practices may adopt EHRs as a subscription service (SaaS) where they only need to maintain an Internet connection and user terminals and everything else is done for them remotely. Large practices may be completely self-contained with their own institutional servers, intranet, backup, terminals and IT staff. Large practice and hospital IT departments will often maintain multiple software environments for the EHR, including distinct and separate production (live), test, and training environments.

Implementation of the EHR is followed by the *post-implementation* phase which remains in effect for the duration of EHR use. This phase involves maintaining, optimizing, reassessing and improving the EHR's content and capabilities, facility workflows/processes, and staff training with a focus on continuous improvement and patient safety. In a sense, EHR implementation is never done. As clinical sites learn more about the software from using it, they often learn how to use the software in previously unanticipated ways. And certainly, as the EHR software is periodically upgraded, new functionality is added that increases efficiencies or opens up new possibilities. Post-implementation can also be referred to as maintenance, sustainment or optimization.

RECOMMENDED READING

- *Efficiency and safety of speech recognition for documentation in the electronic health record* (2017). This article compared standard keyboard documentation with speech recognition (SR) (Dragon) by 35 emergency room physicians using the EHR (Cerner). Participants had prior EHR AND SR training. They were able to demonstrate that task completion was 18% slower with SR and resulted in more errors.[169]

- *Electronic health record adoption in US hospitals: the emergence of a digital "advanced use" divide* (2017). Using 2008-2015 survey data, researchers looked at the prevalance of "basic vs comprehensive" EHRs. New survey questions were sent to establish "performance measurement" and "patient engagement." Their data showed that only 37.5% of hospitals adopted at least 8 of 10 performance measurement functions and 41.7% adopted 8 of 10 paatient engagement functions. They concluded that overall EHR adoption was excellent, but a minority of hospitals had robust systems with performance and patient engagement functionality.[170]
- *HITECH Retrospective: Glass Half-Full or Half-Empty*? (2017). In this blog, Dr. Hersh reviewed several articles in the New England Journal of Medicine that discuss the impact of the HITECH Act. One author points out the increase in HIT adoption as a result of this Act but another bemoans the shorcomings. Dr. Hersh puts this in perspective for the reader.[171]

FUTURE TRENDS

As the practice of healthcare advances EHRs can keep pace by utilizing more sophisticated, integrated and real-time analytics, increasing standardization, enhancing interoperability, and linking tightly with more sophisticated patient portals than those currently available. A desired outcome is that data and information will no longer remain locked in the plethora of EHR silos used by physicians and hospitals, but will electronically flow from one to the other with ease.[172] We can also expect there to be more integration between hospital EHRs and the myriad of medical devices with "smart" attributes, such as IV pumps, blood pressure monitors, glucometers, and other products that may be part of the Internet of Things. Remote patient monitoring, generating data when patients are in their homes or when they are on the move, may also be integrated with the EHR.

Substitutable Medical Applications, Reusable Technologies (SMART) on FHIR is a relatively new initiative that creates apps for EHRs, analogous to smartphone apps. With SMART apps, an API can read data from an EHR and write it to the EHR. As of mid-2017 there were 41 apps posted on a web site., and this number will only grow over time. Figure 4.14 displays a heart failure predictive analytics calculator built using this new paradigm.[173]

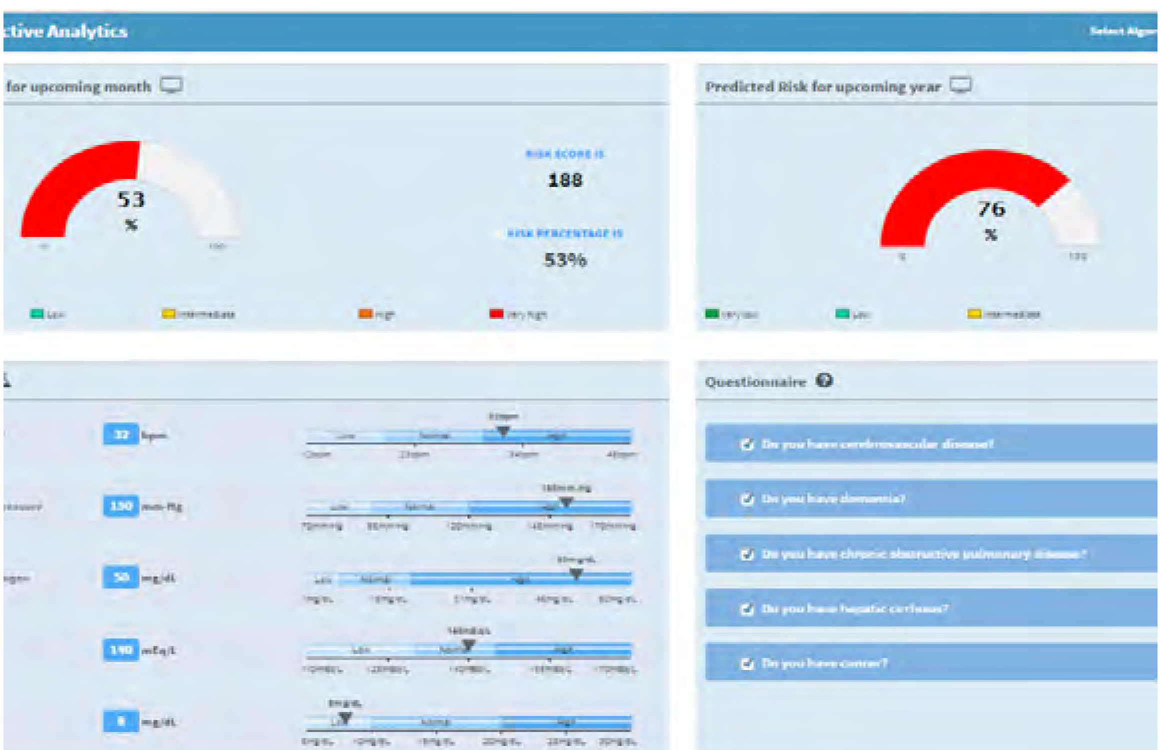

Figure 4.14: SMART on FHIR App

The AMIA EHR-2020 Task Force reported on the status and future direction of EHRs in 2015 with the following recommendations:

- Decrease data entry burden for the clinician, by using patient and other care team input
- Separate data entry from reporting; use natural language processing and new interfaces to produce reports
- EHRs should enable a "*learning healthcare system*" and promote research.
- Regulations should simplify certification, improve interoperability, reduce data re-entry and emphasize patient outcomes.
- Modify reimbursement strategies to support novel EHR innovation
- Enhance EHR certification transparency
- Everyone should be transparent about unintended consequences and best practices to mitigate risk
- EHR vendors should use open APIs, to be open to developers, researchers and patients
- Expand EHR use beyond acute hospital and office care.
- Improve usability[174]

The federal government will continue to look for over-coding and other potential abuses.[175] It is likely there will be new coding guidelines as a result of multiple questions about legitimate EHR billing practices. IT vendors are also being scrutinized, evidenced by the revocation of two EHR certifications in 2013.[176]

Experts suggest several trends, including an increased reliance on cloud computing,[177] and large shared databases used for comparative effectiveness research,[178-179] increased use of natural language processing,[180] more pervasive use of telehealth (virtual visits and consultations),[181] improved clinical decision support, more use of patient registries built into EHR workflow,[182] and greater use and integration of wireless remote outpatient monitoring of patients.[183-184] At least 3 EHR vendors are working on virtual assistants, similar to Amazon's Alexa to save key strokes and time spent looking for results, etc.[185] Rajkomar et al. reported in 2018 their effort to combine FHIR representation, EHR data and deep learning to accurately predict in-hospital mortality and 30 day remission.[186] Clearly, artificial intelligence will be used to improve the EHR's ability to be part of a "*learning healthcare system*."[187]

The Meaningful Use program is transitioning to the QPP, but its future remains uncertain due to budget constraints and a new HHS administration. But no matter how healthcare reimbursement evolves, clearly the direction healthcare is taking is to reimburse for quality and not quantity.

Even today, the future of EHRs is not entirely clear, but one thing is certain – there will be no return to paper records, because much like the advent of the automobile over a century ago rendered the horse-drawn buggy obsolete, the EHR, now used by an entire generation of clinicians who know of no other alternative, will endure.

KEY POINTS

- Electronic health records are central to a modern healthcare system
- Paper-based systems are fraught with multiple shortcomings
- Reimbursement for electronic health records by the federal government dramatically increased EHR adoption
- Despite the potential benefits of electronic health records, obstacles and controversies persist
- Clinical decision support systems are still immature and will likely improve in the future with artificial intelligence
- Advance planning and training is mandatory for successful EHR implementation

CONCLUSION

Without doubt, Medicare and Medicaid reimbursement for EHRs and e-prescribing (the Meaningful Use Program) has been the most significant impetus to promote EHR adoption. However, we lack detailed data regarding EHR failure rates, and are still learning lessons from MU stages 1 and 2.

Enterprise-scale clinical information systems have been transformational for large organizations like the VA, Kaiser-Permanente and the Cleveland Clinic, but the reality is that medicine in this country is mostly practiced by small medical groups, with limited finances and IT support. As a new trend, we are seeing outpatient clinicians opt to re-engineer their business model centered on an EHR. Their goal is to reduce overhead by having fewer support staff and to concentrate on seeing fewer patients per day but with more time spent per patient. When this is combined with secure messaging, e-visits and e-prescribing the goal of the *e-office* is achievable.[188]

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