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# Clinical Informatics

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**LEARNING OBJECTIVES**

1. Define the major terminology of clinical informatics and related topics.
2. Describe the role of clinical informatics in health care delivery.
3. Discuss the secondary uses of clinical data.
4. Describe the outcomes of the applications of clinical informatics in health care delivery.

This chapter begins by describing the importance and relevance of health information technology and clinical informatics to safe and effective patient care. Applications of clinical informatics, particularly the electronic health record (EHR), are discussed. The value of the EHR in supporting high-quality patient care and the importance of EHR interoperability are emphasized. Next, the use of data analytics to support various information needs of health care providers and health systems are elucidated. Challenges and opportunities related to the use of EHRs and informatics are presented. Lastly, the authors highlight recently developed competencies in clinical informatics and briefly reflect on future directions in this increasingly important area in health care and medical education. Throughout the chapter, key terms and concepts are defined and described.

**CHAPTER OUTLINE**



The optimal delivery of health care requires information. The discipline devoted to the efficient storage, acquisition, and use of information in health care is called *biomedical and health informatics.*[1] The area within the discipline of informatics focused on health care delivery is known as *clinical informatics*. This chapter focuses on how clinical informatics can be used to improve the quality, safety, and efficiency of health care delivery.

## I. RATIONALE AND TERMINOLOGY OF CLINICAL INFORMATICS

The importance of clinical informatics in health care delivery began to emerge in the latter part of the 20th century. A series of seminal reports from the Institute of Medicine (IOM) documented significant problems in health care delivery and led to proposed solutions based on best information technology (IT) and evidence supporting its use. The first IOM report documented the harms resulting from incomplete and illegible paper-based medical records.[2] Probably the most high-profile of these reports focused on errors in hospitals estimated to result in up to 96,000 deaths per year.[3] Another IOM report noted a "chasm" of deficiencies in the quality of health care between the known, evidence-based best practices and their actual use in the health care system. Constraints on exploiting the revolution in information technology was named as one of the underlying reasons for inadequate quality of care, and increasing the use of information technology was cited as a means of improving quality of care.[4]

A number of studies supported the conclusions of these reports. In 1995, Bates and colleagues documented error rates of 6.5 adverse drug events (ADEs) per 100 hospitalized patients.[5] Quality problems were quantified more clearly in 2003 by McGlynn and coworkers, who assessed the records of 6259 patients in 12 metropolitan areas and found that only 54.9 percent of care delivered was consistent with evidence-based known best practices.[6] Paper-based medical information was associated with clinical decisions being made with incomplete information, as Smith and colleagues showed that information was missing and impacted up to 44 percent of patients in primary care settings.[7]

## A. Value of Clinical Informatics in Improving the Quality, Safety, and Efficiency of Health Care

Additionally, there was emerging evidence for the value of health IT. In 1993, Tierney and colleagues documented that **computerized provider order entry (CPOE)** in hospitals was associated with a 12.7 percent decrease in total charges and a 0.9-day shorter length of stay.[8] in 1998, Bates and colleagues showed that CPOE reduced serious medication errors by 55 percent, with adverse drug events reduced by 17 percent.[9] Other studies showed that CPOE led to a reduction in redundant laboratory tests[10] and increased prescribing of equally efficacious but less costly medications.[11] Much of this early work was summarized in a systematic review of 257 studies of health IT documenting its association with increased adherence to guideline-based care, enhanced surveillance and monitoring, and decreased medical errors.[12]

Modeling studies were also being published demonstrating return on investment for electronic health records (EHRs) as well as **health information exchange (HIE),** the exchange of information across the boundaries of health care organizations.[13] Johnston and colleagues assessed the potential benefit of CPOE in ambulatory settings and noted savings of up to $28,000 per year, although most of the savings went to laboratories and insurance companies, and not the physician practices making the investment.[14] Another modeling study by Hillestad and coworkers applied results of known research in an attempt to scale to the entire US health care system, finding that HIE could potentially result in savings of $81 billion per year above costs and a reduction of 200,000 ADEs per year.[15]

## B. ARRA, HITECH, and Adoption of Electronic Health Records

When these problems were considered in the context of an ongoing economic recession and a new president whose priorities included health care reform, the time was ripe for a substantial national investment in EHR adoption. One of the first acts of President Barack Obama's tenure was the passage of the American Recovery and Reinvestment Act (ARRA), a $787 billion economic stimulus that included the Health Information Technology for Economic and Clinical Health (HITECH) Act, which allocated approximately $30 billion for investment in the adoption of EHRs.[16] Such an investment was the type of "shovel ready" project needed for the stimulus, and there was additional evidence that such an investment could create tens of thousands of jobs in the health IT sector.[17] There already existed a template for the concept of "meaningful use" to measure adoption for incentive purposes that had been put forth earlier by Congressman Pete Stark.[18]

Since its inception in 2010, the HITECH Act has led to substantial growth of EHR adoption, with nearly all hospitals (96 percent)[19] and over four-fifths of office-based physicians (83 percent)[20] now using them. However, many challenges have emerged with the introduction of EHRs into health care, such as disruption in workflow, increased time required for patient documentation, and distraction by the computer in the examination room,[21] providing further imperative for the optimal understanding and application of clinical informatics.

## C. Definitions of Informatics and Related Terms

A critical aspect of informatics is its focus on information and not technology. While IT infrastructure (i.e., the networks, devices, and software) is essential for effective application of informatics, the larger goal is the benefit that information provides to health care and optimal health of individuals and populations.[1,22,23] Friedman has defined the "fundamental theorem" of informatics, which states that informatics is more about using technology to help people perform their work better than about building systems to mimic or replace human expertise.[24] He has also described what informatics is (information sciences applied in a biomedical application domain with the aim of helping people) and is not (any use of IT or data analysis in health care).[25]

While informatics is a relatively new discipline compared to others in medicine, it has accumulated a history over a half-century that has evolved with advances in IT.[26] The various areas within biomedical and health informatics are depicted in Fig. 9.1. Sometimes narrower words appear in front of informatics. *Clinical informatics* generally refers to informatics applied in health care settings.[27] Sometimes *medical informatics* is used to describe this application as well. Other uses of informatics in biomedical and health-related areas include the following:

- *Bioinformatics*—the application of informatics in cellular and molecular biology, often with a focus on genomics[28]
- *Imaging informatics*—informatics with a focus on imaging, including the use of systems to store and retrieve images in health care settings[29]
- The application of informatics focused on specific health care disciplines, such as nursing *(nursing informatics),*[30] dentistry *(dental informatics),* pathology *(pathology informatics),*[31] and so on
- *Consumer health informatics*—the field devoted to informatics from a consumer view[32]
- *Clinical research informatics*—the use of informatics to facilitate clinical research, with increasing emphasis on translational research that aims to accelerate research findings into clinical practice[33]
- *Public health informatics*—the application of informatics in areas of public health, including surveillance, reporting, and health promotion[34]

## D. Subspecialty Certification in Clinical Informatics

Even though not limited to the work of physicians, clinical informatics is now recognized as a medical subspecialty[27] and has been defined by the Accreditation Council for Graduate Medical Education (ACGME) as the field that "transforms health care by analyzing, designing, implementing, and evaluating information and communication systems to improve patient care, enhance access to care, advance individual and population health outcomes, and strengthen the

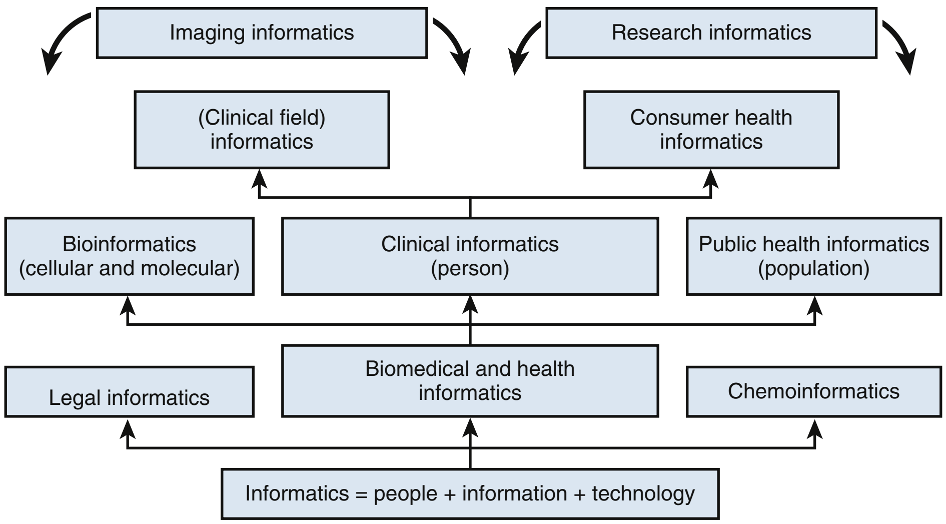


**Fig. 9.1 Areas within biomedical and health informatics, including clinical informatics.** (Adapted from Hersh W. A stimulus to define informatics and health information technology. *BMC Med Inform Decis Mak.* 2009;9:24. http://www.biomedcentral.com/1472-6947/9/24/.)

clinician-patient relationship."[35] Since 2013, physicians who have worked in the field or completed a fellowship in informatics and have a primary board certification in their specialty have been eligible to become board certified in clinical informatics. That subspecialty certification is available to physician specialists who are certified by any of the 24 member boards of the American Board of Medical Specialties, which endorses the broad clinical relevance of expertise in clinical informatics.[27] Since the first certification examination was offered in 2013, over 1100 physicians have become board-certified.

## II. USE OF CLINICAL INFORMATICS IN HEALTH CARE DELIVERY

There are many applications of clinical informatics, with the EHR occupying a central role. The EHR serves several key functions, not only in documenting data and information of care delivery, but also providing access to other participants in the system, most importantly the patient, and it functions to improve care delivery.

### A. Electronic Health Records

Probably the most central application of clinical informatics is the EHR. In the past, the term electronic medical record (EMR) was more commonly used, but EHR implies a broader and more longitudinal collection of information about the patient. There is also increasing use of the term personal health record (PHR). This usually refers to the patient-controlled aspect of the health record and may or may not be tethered to one or more EHRs from health care delivery organizations. There are a growing number of cloud-based PHR products available in which patients are able to manage their own health record.

The EHR is not meant to be a mere replacement for the paper-based record, but rather it should ideally serve as a tool to transform and improve health care delivery. One major component of the EHR is **clinical decision support (CDS),** which allows detection of errors and adverse events and can facilitate improved care delivery and quality.[36] As the most critical time for intervention is when the physician is entering patient orders, the function of the CPOE is the optimal time to make CDS readily available. Related to CPOE is electronic prescribing (e-prescribing), which focuses more narrowly on the electronic ordering of medications. The major categories of CDS include the following:

- Information display—showing general or patient-specific information in context of the current clinical situation
- Reminder systems—reminding clinicians to perform actions, such as preventive measures, when they are due
- Alerts—alerting to critical clinical situations (e.g., interacting drugs, abnormal laboratory values that may negatively impact patient safety and health outcomes)
- Clinical practice guidelines—guiding treatment to provide consistent care based on best evidence

An exemplar EHR is the Veterans Health Information Systems and Technology Architecture (VistA) system (http://www.ehealth.va.gov/vista.asp), which is used in 1800 locations across the world including all Department of Veterans Affairs medical centers as well as by the national health systems of Finland, Egypt, and Jordan. Fig. 9.2 shows the cover page of the EHR, which provides an overview of the patient, including his or her active problems and medications as well as recent results. This page also shows an example of CDS, listing all clinical reminders. The tabs at the bottom of the screen allow the user to drill down into more details on specific aspects of the patient's care, such as medications and laboratory results. Many of these screens feature additional CDS, such as drug-drug interactions.

As the use of EHRs has grown, it has become apparent that information must seamlessly flow among health care providers, and it must flow across different health care organizations. This has led to growing advocacy for HIE, which is the exchange of health information for patient care across traditional business boundaries in health care. Even many health care organizations that have exemplary HIT systems have difficulty providing their patient information to other entities where the patient may receive care. An increasingly mobile population also needs to have "data following the patient" as patients move in, out, and across health care systems.

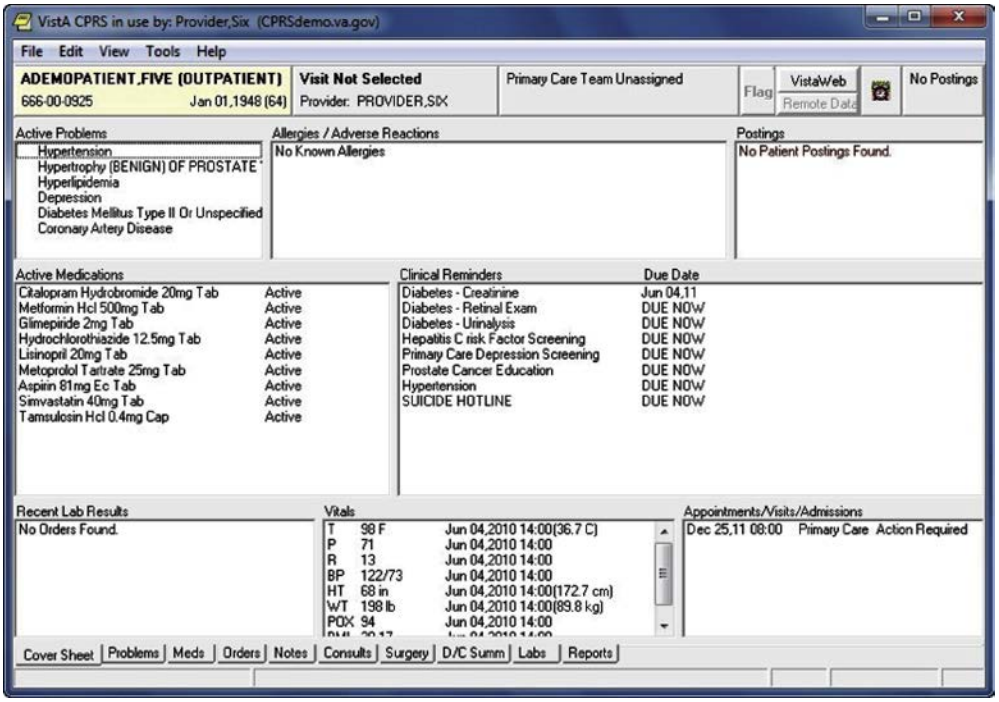


**Fig. 9.2 Cover page of the Veterans Health Information Systems and Technology Architecture system.** (VistA, http://www.ehealth.va.gov/vista.asp.)

## B. Electronic Health Record Interoperability

One of the impediments to HIE has been suboptimal **interoperability** of EHR systems, with systems unable to seamlessly exchange data. Optimal interoperability requires adoption and adherence to standards to define data structures and formats. Although many standards exist for exchange of information and consistent use of terminology, they have not been applied for a variety of reasons.[37] The major categories of standards include the following:

- Identifiers—of patients, clinicians, health plans, insurance companies, and so on
- Transactions—eligibility, enrollment, payments, and so on
- Message exchange—transmission of data, images, documents, and so on
- Terminology—standard descriptions of diagnoses, tests, treatments, and so on

The presence of standardized interoperable data and systems not only leads to improved direct care of patients but also to secondary use or re-use of clinical data, where data from clinical settings is used for other applications, such as quality measurement and improvement, clinical and translational research, and public health.[38] All of these systems come together in the concept advanced by the IOM of the **learning health system.**[39,40]

## C. Beyond the Electronic Health Record

Clinical informatics is not limited to EHRs. Another vital component for optimal patient care is access to information and knowledge. The field devoted to indexing and retrieval of knowledge-based information is called information retrieval or search.[41] Searching is a basic skill in the practice of **evidence-based medicine** (EBM), a skill set that includes the proper phrasing of clinical questions, seeking the best evidence to answer such questions, critically appraising what was retrieved, and applying such evidence to patient care. One recent textbook of EBM notes, “Searching for current best evidence in the medical literature has become a central skill in clinical practice. On average, clinicians have 5 to 8 questions about individual patients per daily shift… Some now even consider that ‘the use of search engines is as essential as the stethoscope.’”[42]

Additional important applications of clinical informatics are telemedicine and telehealth.[43] **Telemedicine** is the delivery of health care when the participants are separated by time and/or distance, while telehealth has a larger aspect of all telecommunications applications devoted to health. As with informatics, the “tele-” terms sometimes reflect medical specialties in which they are applied (e.g., teleradiology, telepathology). A variety of practice models embracing telehealth have now emerged, including e-ICU and telestroke services that are commonly employed to deliver expertise to a broader population.

Table 9.1 lists some of the other chapters and their titles in this book and the role that informatics plays within them.

# III. RE-USE OF CLINICAL DATA

One of the promises of the growing critical mass of clinical data accumulating in the EHR is secondary use (or re-use) of the data for other purposes, such as quality improvement, operations management, and clinical research.[38] There has also been substantial growth in other kinds of health-related data, most notably through efforts to sequence genomes and other biological structures and functions. The analysis of this data is usually called analytics or **data analytics.**[44]

**Table 9.1 Role of Clinical Informatics in Topics Covered in Other Select Chapters**

| Chapter | Title | Role of Clinical Informatics |
|---|---|---|
| 3 | The Health Care Delivery System | Documenting and improving care |
| 4 | Value in Health Care | Providing decision support to achieve value |
| 5 | Patient Safety | Early detection and action upon safety issues |
| 6 | Quality Improvement | Measurement and improvement of quality |
| 7 | Principles of Teamwork and Team Science | Facilitating care coordination among teams |
| 8 | Leadership in Health Care | Allowing leaders to make better decisions |
| 10 | Population Health | Management and surveillance of populations |
| 11 | Socio-Ecologic Determinants of Health | Determination and action to reduce disparities |
| 12 | Health Care Policy and Economics | More informed policy decisions |
| 13 | Application Foundational Skills to Health Systems Science | Access to evidence-based information |
| 14 | The Use of Assessment to Support Learning and Improvement in Health Systems Science | Access to quality data and clinical evidence to improve delivery of care |

## A. Data Analytics

The terminology surrounding the use of large and varied types of data in health care is evolving, but the term analytics is achieving wide use both in and out of health care. A long-time leader in the field defines analytics as “the extensive use of data, statistical and quantitative analysis, explanatory and predictive models, and fact-based management to drive decisions and actions.”[45] The company IBM defines analytics as “the systematic use of data and related business insights developed through applied analytical disciplines (e.g., statistical, contextual, quantitative, predictive, cognitive, other [including emerging] models) to drive fact-based decision making for planning, management, measurement and learning. Analytics may be descriptive, predictive or prescriptive.”[46]

Adams and Klein have authored a primer on analytics in health care that defines different levels and their attributes of the application of analytics.[47] They noted three levels of analytics, each with increasing functionality and value:

- Descriptive—standard types of reporting that describe current situations and problems (e.g., reports of patients with certain diagnoses or outlier test results)
- Predictive—simulation and modeling techniques that identify trends and portend outcomes of actions taken (e.g., lists of patients who may be at risk for poor outcomes or repeated admissions to the hospital)
- Prescriptive—optimizing clinical, financial, and other outcomes (e.g., recommendations for patients to maintain health or to prevent poor outcomes)

Much work is focusing now on **predictive analytics,** especially in clinical settings attempting to optimize health and financial outcomes, including in clinical practice.[48]

There are a number of terms related to data analytics. A core methodology in data analytics is machine learning, which is the area of computer science that aims to build systems and algorithms that learn from data.[49] One of the major techniques of machine learning is data mining, which is defined as the processing and modeling of large amounts of data to discover previously unknown patterns or relationships.[50] A sub-area of data mining is text mining, which applies data mining techniques to mostly unstructured textual data.[51] Another close but more recent term in the vernacular is big data, which describes large and ever-increasing volumes of data that adhere to the following attributes:[52]

- Volume—ever-increasing amounts
- Velocity—quickly generated
- Variety—many different types
- Veracity—from sources whose trustworthiness can be known

## B. Making Use of Data

Hospitals and other health care organizations are generating an exploding amount of data. Clinical data takes a variety of forms, from structured (e.g., images, laboratory results) to unstructured (e.g., textual notes including clinical narratives, reports, and other types of documents). Additionally, health care organizations capture and generate additional data as a byproduct of the care delivery process. This can include billing, quality, management, and other financial data, which are increasingly important in the optimization of health care delivery. Kaiser Permanente estimated in 2013 that its data store for its 9+ million members exceeds 30 petabytes of data.[53] Other organizations are planning for a data-intensive future. For example, the American Society for Clinical Oncology (ASCO) has been developing its Cancer Learning Intelligence Network for Quality (CancerLinQ).[54] CancerLinQ will provide a comprehensive system for clinicians and researchers consisting of EHR data collection, application of CDS, data mining and visualization, and quality measurement for improvement.

The world’s growing base of scientific literature and its underlying data that are increasingly published with journal and other articles is another source of data and can be linked with EHR and other patient data aiming to improve outcomes of care. One approach to this problem that has generated attention is the IBM Watson project, which was made famous by winning at the television game show *Jeopardy!*[55] One of the areas where IBM and its partners have been applying Watson is in the health care arena.[56]

The growing quantity of data requires that its users have a good understanding of its provenance, which is where the data originated and how trustworthy it is for large-scale processing and analysis.[57] A number of researchers and thought leaders have started to specify the path that will be required for big data to be applied in health care and biomedicine.[58–60] Bates and colleagues elucidated a number of use cases in which big data methods might lead to improved outcomes[61]:

- High-cost patients—looking for ways to intervene early
- Re-admissions—prevention
- Triage—appropriate level of care
- Decompensation—when a patient's condition worsens
- Adverse events—awareness
- Treatment optimization—especially for diseases affecting multiple organ systems

Patients are also increasingly interested in seeing more than just basic transactional information (i.e., a test result or a notice of an overdue payment). They want summarized information along with recommendations for care that is personalized to them. Similarly, payers, providers, and health care institutions are all increasingly seeking information that can help them predict how to better serve their customers, clients, and patients.

A more peripheral but related term is business intelligence, which in health care refers to the "processes and technologies used to obtain timely, valuable insights into business and clinical data."[47] Another relevant term is the notion promoted by the IOM of the learning health system.[39,40] Advocates of this approach note that routinely collected data can be used for continuous learning to allow the health care system to better carry out disease surveillance and response, targeting of health care services, improving decision-making, managing misinformation, reducing harm, avoiding costly errors, and advancing clinical research.[62]

Another set of related terms come from the call for new and much more data-intensive approaches for diagnosis and treatment of disease, originally called personalized medicine[63] but now labeled precision medicine (i.e., identifying which approaches will be effective for which patients based on genetic, environmental, and lifestyle factors).[64] Pharmacogenomics is a subset of precision medicine that studies how genetics affect a person's response to particular drugs. The US government has recently committed a substantial investment in research around precision medicine.[65] But probably the major motivator for data-driven decision making in health care is the move from volume-driven reimbursement (e.g., fee for service) to value-driven reimbursement (in which health systems and providers share risk).[66]

As clinical data accumulate, so does the amount of metadata (or data about data). **Metadata** can be defined as data points used to identify data (e.g., who authored a particular clinical note) or how data are linked together (e.g., vital signs from multiple records that represent a single patient) or how data have been utilized (e.g., data access and audit logs). Analysis of metadata, rather than the underlying clinical data itself, can be informative. In the United States, since 1996, the Health Insurance Portability and Accountability Act (HIPAA) requires that hospitals maintain audit trails for 6 years. Metadata have been used by many researchers to understand health care processes in support of quality improvement. For example, one research team utilized audit log metadata to evaluate the composition of medical teams. They found that 25 percent of clinicians in their hospital had at least one contact with an obstetric patient over the course of 1 year representing over 300 clinicians. Another common place where metadata are used is in the process of understanding clinical workflows. A study of residents using EHR audit metadata revealed that they tended to view computed tomography scans themselves, while relying on the attending radiologist's chest radiograph film reports. The study also found that more senior residents viewed images more frequently than junior residents, who also viewed images more often than medical students.[67]

## Case Study 1

One Saturday evening, an elderly patient who lives in a suburb of Indianapolis develops sharp abdominal pain while visiting her sister in northern Indiana. The patient, who has difficulty keeping track of her medicines, decides to go to the local emergency department. During the triage process, the patient is asked to provide information about her medical history and a current list of medications. She is unable to provide much information given her limited capacity. Given that her regular doctor's office is closed and she is at a hospital she has never visited, what steps can the treating team use to provide the best patient-centered care for this patient? Is there a way that technology can help fill in the gaps?

The *Indiana Network for Patient Care* (INPC) is part of the Indiana Health Information Exchange (IHIE, www.ihie.org), which is one of the largest and original health information exchange (HIE) efforts in the world. The IHIE allows over 100 hospitals and 22,000 physicians, along with long-term care facilities, laboratories, and public health organizations to share data for patient care, research, public health, and other purposes.[68] The INPC is the data repository that enables the IHIE, with over 11 million patients and 4 billion structured observations. The emergency departments of all hospitals can access the records of patients who have received care at any IHIE-connected hospital, with the physicians able to query laboratory, radiology, and other reports of all patients in the INPC repository.

The INPC facilitates a number of best practices to use for improving patient care. A few examples include when patients present in the following situations[115]:

- Emergency department—accessing recent care activity and results from other care settings to reduce unnecessary redundant testing, facilitate medication reconciliation, and help clinicians identify patients who are at risk for medication abuse and "doctor shopping"; the HIE is particularly helpful when patients present after hours for urgent conditions
- Inpatient—providing a more complete picture of the patient at admission and facilitating medication reconciliation
- Case management—allowing better coordination of care and reducing redundant testing
- Radiology departments and centers—providing results for comparative assessment and reducing cost and radiation exposure
- Outpatient—preparing the chart prior to patient arrival and providing information about past visits to develop a more informed care plan
- Quality and performance improvement—accessing data for quality measures
- Accountable Care Organization (ACO) managers—facilitating access to information about the patient's care, including outside the ACO
- Long-term care—improving transitions of care and providing information when the patient needs to visit the emergency department or outpatient settings

### C. Formulating Questions

The true utility of clinical data and metadata can only be realized when one is able to use these resources to answer relevant questions. Formulating such a question begins with a problem statement and an understanding of the underlying data that are available to help provide an answer. Treatment of the data and selecting an appropriate analytical approach should be the final step. For example, one might ask, "How often do medical students participate in vaginal deliveries?" or "How often are surgical cases canceled the morning of surgery?" Depending on the data available in the EHR, these types of questions might be easily answered by relatively simple case log queries. More complex questions such as "How often are dialysis patients re-admitted within 30 days after AV-fistula creation due to a surgical complication" pose more challenges, depending on how the underlying data are stored. In the latter example, most EHRs can provide admission and re-admission data, but fewer store the data on the reason for a re-admission in a structured fashion. Depending on what data are available in a particular system, the question about re-admissions from surgical complications may or may not be able to be answered using data queried from an EHR.

### D. Clinical Data Warehousing, Registries, and Quality Reporting

**Clinical data warehouses** are central repositories of data where information is integrated together from disparate sources. They are typically maintained at the institutional level (i.e., within a hospital or health care system). **Clinical data registries** are collections of data about patients with a similar disease or therapeutic process. For example, the Cancer Genetics Network collects data about patients with cancer, and the Society of Thoracic Surgeons Database collects data from 1100 hospitals about patients who have undergone cardiothoracic surgery. The Multicenter Perioperative Outcomes Groups (MPOG) is a consortium of 47 medical centers that share anesthesia and surgical outcomes data. In 2014, the federal government created a standardized approach reporting clinical data registries through the Qualified Clinical Data Registry (QCDR) reporting mechanism. This was an attempt to motivate physicians to collect clinical data to foster quality improvement and to penalize those who did not through a system of reimbursement incentives and penalties.

The case study in this chapter describes the Indiana Network for Patient Care (INPC), an HIE implementation that covers most of Indiana and provides data that facilitate care in hospitals, emergency departments, outpatient settings, long-term care facilities, and public health agencies.[68] Data from the INPC not only improve access to data for direct care but also facilitate population health management and calculation of quality measures. Although HIE efforts have been challenging to generalize, they have been associated with improved quality and efficiency of care.[69]

### E. Challenges for Data Analytics

A concern for more intensive use of data is that data generated in the routine care of patients may be limited for analytical purposes.[70] For example, such data may be inaccurate or incomplete. It may be transformed in ways that undermine its meaning (e.g., coding for billing priorities). For example, services or diagnoses that are highly reimbursed may be coded more reliably than other entities. It may exhibit the well-known statistical phenomenon of *censoring*, for example, the first instance of disease in record may not be when it was first manifested (left censoring) or the data source may not cover a sufficiently long time interval (right censoring). Data may also incompletely adhere to well-known standards, which makes combining it from different sources more difficult.

There is an emerging base of research that demonstrates how data from operational clinical systems can be used to identify critical situations or patients whose costs are outliers. There is less research, however, demonstrating how these data can be put to use to actually improve clinical outcomes or reduce costs. Studies using EHR data for clinical prediction have been proliferating. One common area of focus has been the use of data analytics to identify patients at risk for hospital re-admission within 30 days of discharge. The importance of this factor stems from the US Centers for Medicare and Medicaid Services (CMS) Readmissions Reduction Program that penalizes hospitals for excessive rates of re-admissions.[71] This has led several researchers to assess EHR data in its value to predict patients at risk for re-admission.[72–74]

## IV. OUTCOMES AND IMPLICATIONS OF CLINICAL INFORMATICS

With the massive adoption of EHRs in the United States driven by the HITECH Act, there has been a dichotomy between focused research describing specific benefits and general dissatisfaction with current systems and their impact on medical practice. Following the original systematic review in 2006, three subsequent reviews using a similar methodology published in 2009,[75] 2011,[76] and 2014[77] have shown persistent benefits for health IT.

### A. Adverse Effects of Electronic Health Records

At the same time, there have been great concerns about the adverse impact of EHR use in health care delivery. A number of surveys have documented substantial dissatisfaction among EHR users[78] and identified EHRs as a major source of physician dissatisfaction in medical practice.[79] It is unknown whether this is a temporary transitional problem to better systems or will result in ongoing problems with their use in medical practice.[21]

Among the problems of EHRs emerging include excess focus on the computer over the patient,[80,81] the demise of traditional communications such as radiology rounds,[82] and problems with documentation such as losing the patient's story through use of documentation templates[83] and inappropriate use of "copy and paste."[84]

Although EHRs have been touted to improve patient safety, there are also growing concerns that some aspects of their use may introduce new safety problems.[85] Two recent high-profile mishaps included massive overdosing of a common antibiotic[86] and accidental discharge of a patient who was infected with the Ebola virus.[87] There are also growing concerns over the security of health information.[88] The year 2015 saw several massive security breaches, leading to exposure of records of over 100 million Americans.[89–91] The black market value of a medical record has been estimated to be 10 times that of a credit card number.[92]

Nonetheless, there are many who believe that we should continue to improve EHRs and leverage their benefits to improve health care delivery. Two high-profile professional organizations have issued white papers specifying improvements in the EHR[93] and patient documentation.[94] The American Medical Association has laid out the following set of principles for improved usability and interoperability:[95]

- Enhance physicians' ability to provide high-quality patient care
- Support team-based care
- Promote care coordination
- Offer product modularity and configurability
- Reduce cognitive workload
- Promote data liquidity
- Facilitate digital and mobile patient engagement
- Expedite user input into product design and post-implementation feedback

## B. Benefits of Electronic Health Records

In balance, a (mostly) positive evidence base continues to accumulate on EHR use. Evidence in support of the value of EHRs shows that they detect and help overcome delays in cancer diagnosis,[96,97] reduce risk of hospital re-admission,[98,99] and improve identification of postoperative complications.[100] EHRs have also been shown to enhance patient-provider communication[101] and facilitate research through extracting phenotype information about patients.[102,103] Within the surgical patients, EHRs have been shown to improve care in a number of ways by reducing postoperative nausea and vomiting, surgical site infections, and wrong-sided surgeries.[104] There are even emerging models for more optimal examination room use of EHRs.[105] Optimists continue to note other benefits, such as the "data dividend" of EHR adoption from the HITECH Act.[106] Others note that problems with diagnostic[107] and therapeutic[108] errors in health care continue.

## C. Clinical Informatics Research: Challenges and Opportunities

Informatics has a tremendous potential to facilitate both high-quality outcomes research and quality improvement efforts. EHRs, data warehouses, and clinical registries are all tools that have become ubiquitous across health care. New approaches to data storage, management, and analysis are enabling a growing number of end-users the ability to turn data into information with greater ease. These tools, when taken together, can be used to identify patients or processes of interests, obtain data, and study interventions in ways that have been impossible heretofore. Additionally, clinical data that is re-used for these purposes often come at a fraction of the price of data that have to be manually extracted or collected by research personnel. The success of these efforts, however, is dependent on data quality, standards, and availability. Additionally, overcoming the regulatory challenges associated with data sharing and privacy concerns remains a significant issue. Finally, none of this work is possible without expert informaticians who are able to lead these efforts.

# V. COMPETENCIES OF CLINICAL INFORMATICS

Health care providers, including physicians and medical students, have been using health IT for decades. During this time, the role of health IT has changed dramatically from a useful tool for data access and occasional information retrieval to a ubiquitous presence that permeates health care and medical practice in many ways. But 21st-century clinicians face a clinical world that is quite different from that of their predecessors. The quantity of biomedical knowledge continues to expand, with an attendant increase in the primary scientific literature.[109] Secondary sources that summarize this information proliferate as well, not only for use by clinicians but also by patients and those who are healthy but consuming health-related information. The accelerated adoption of EHRs under the HITECH Act requires competency in their use, including for secondary uses as discussed earlier. Patients want to interact with the health care system the same way they interact with airlines, banks, and retailers, that is, through digital means using technologies such as the PHR.[110] Patients, payers, and purchasers demand more accountability in health care quality, safety, and cost,[111] leading to an expectation of measurement and reporting of quality of care as a routine part of participation in new delivery mechanisms such as primary care medical homes and accountable care organizations. These trends emphasize the need for health care professionals to develop and maintain the knowledge and skills necessary to use clinical informatics optimally in delivering safe and effective patient care. Table 9.2 lists competencies developed for medical education but has application for physicians beyond medical school and other health care professionals.[112]

While all physicians need basic competence in clinical informatics, there is also a need for a modest-sized cadre of experts in the area. Growing numbers of physicians assume roles in health care settings under titles such as Chief Medical Informatics Officer (CMIO).[113] There are also opportunities in industry, government, and other settings. These opportunities have led to the designation of a new medical subspecialty (of all medical specialties) of clinical informatics.[27] Since 2013, over 1100 physicians practicing clinical informatics have been able to become board-certified in this new subspecialty. In addition, fellowship programs accredited by the ACGME are starting to be established.[114] This underscores the need for introduction of the concepts and competencies of clinical informatics as part of medical training.

**Table 9.2 Competencies in Clinical Informatics for Health Care Professionals[112]**

1. Find, search, and apply knowledge-based information to patient care and other clinical tasks
   a. Information retrieval/search: Choose correct source for specific task, search using advanced features, apply results
   b. Evaluate information resources (e.g., literature, databases) for their quality, funding sources, biases
   c. Identify tools to assess patient safety (e.g., medication interactions)
   d. Utilize knowledge-based tools to answer clinical questions at the point of care (e.g., text resources, calculators)
   e. Formulate an answerable clinical question
   f. Determine the costs/charges of medications and tests
   g. Identify deviations from normal (laboratory tests/radiographs/results), and develop a list of causes of the deviation
2. Effectively read and write from the electronic health record for patient care and other clinical activities
   a. Graph, display, and trend vital signs and laboratory values over time
   b. Adopt a uniform method of reviewing a patient record
   c. Create and maintain an accurate problem list
   d. Recognize medical safety issues related to poor chart maintenance
   e. Identify a normal range of results for a specific patient
   f. Access and compare radiographs over time
   g. Identify inaccuracies in the problem list/history/medication list/allergies
   h. Create useable notes
   i. Write orders and prescriptions
   j. List common errors with data entry (e.g., drop-down lists, copy and paste)
3. Use and guide implementation of clinical decision support (CDS)
   a. Recognize different types of CDS
   b. Be able to use different types of CDS
   c. Work with clinical and informatics colleagues to guide CDS use in clinical settings
4. Provide care using population health management approaches
   a. Utilize patient record (data collection and data entry) to assist with disease management
   b. Create reports for populations in different health care delivery systems
   c. Use and apply data in accountable care, care coordination, and the primary care medical home settings
5. Protect patient privacy and security
   a. Use security features of information systems
   b. Adhere to HIPAA privacy and security regulations
   c. Describe and manage ethical issues in privacy and security
6. Use information technology to improve patient safety
   a. Perform a root-cause analysis to uncover patient safety problems
   b. Become familiar with safety issues
   c. Use resources to solve safety issues
7. Engage in quality measurement selection and improvement
   a. Recognize the types and limitations of different types of quality measures
   b. Determine the pros and cons of a quality measure, how to measure it, and how to use it to change care
8. Use health information exchange (HIE) to identify and access patient information across clinical settings
   a. Recognize issues of dispersed patient information across clinical locations
   b. Participate in the use of the HIE to improve clinical care
9. Engage patients to improve their health and care delivery though personal health records and patient portals
   a. Instruct patients in the proper use of a personal health record (PHR)
   b. Write an e-mail to a patient using a patient portal
   c. Demonstrate appropriate written communication with all members of the health care team
   d. Integrate technology into patient education (e.g., decision-making tools, diagrams, patient education)
   e. Educate patients to discern quality of online medical resources (e.g., websites, apps, patient support groups, social media)
   f. Maintain patient engagement while using an EHR (e.g., eye contact, body language)
10. Maintain professionalism through use of information technology tools
   a. Describe and manage ethics of media use (cloud storage issues, texting, cell phones, social media professionalism)
11. Provide clinical care via telemedicine, and refer those for whom it is necessary
   a. Be able to function clinically in telemedicine/telehealth environments
12. Apply personalized/precision medicine
   a. Recognize the growing role of genomics and personalized medicine in care
   b. Identify resources enabling access to actionable information related to precision medicine
13. Participate in practice-based clinical and translational research
   a. Use EHR alerts and other tools to identify patients and populations for offering clinical trial participation
   b. Participate in practice-based research to advance medical knowledge

## VI. CHAPTER SUMMARY

Across health care, major changes have been spawned by innovation, regulatory efforts, and consumer demands. All three are likely to play a role in shaping the future of clinical informatics. We will undoubtedly see continued innovation, as technology evolves and continues to permeate our health care delivery systems. The government, through its purchasing power, regulatory requirements, and incentive programs, is also likely to shape the use of clinical informatics. What is less clear is what role consumers will play. Some predict that consumer demand for access to health care information will drive changes to EHRs, interoperability, information exchange, and the use of personal health records. Others predict that today's EHRs will be replaced entirely by cloud-based approaches to managing health IT. Regardless of what the future holds, clinical informatics will be an important tool in optimizing the care we deliver to our patients.

One of the ongoing challenges facing our health care system is the need for astute clinicians who understand how information systems work and can provide leadership in the design and redesign of our medical systems. Many challenges arise when information systems are either developed or implemented without a clear understanding of the clinical workflow or how end-users (i.e. clinicians) intend to use them. While many EHR vendors employ clinicians in a variety of advisory capacities, even well-designed systems can fail if not implemented in a way that matches the local workflow of a given clinical environment. For example, a nursing flow sheet that is optimized for an intensive care unit may not work for an outpatient clinic. Hence the increased adoption, reliance, and importance of EHRs is creating more demand for informaticians.

## QUESTIONS FOR FURTHER THOUGHT

1. What forms of clinical decision support (CDS) are available for use in association with electronic health records (EHRs), and how might they help enhance the safety and quality of health care?
2. What are the three types of data analytics, and how can each one help in managing or improving the value of care provided to a population of patients?
3. What are some of the areas in which the use of big data can potentially lead to improved health outcomes?
4. Why have EHRs not obtained uniform support within the patient and physician communities?
5. Which of the clinical informatics competencies do you feel least comfortable with, and how can you target your learning activities and clinical experiences to improve your knowledge and skills in these areas?

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