Chapter 10
Health Information Systems and Applications

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Learning Objectives

- Describe the four key functions of a health information system
- Understand the difference between patient-specific and knowledge-based data
- Give examples of clinical versus administrative data
- Identify advantages and disadvantages of structured versus unstructured data
- Identify common applications of health information systems
- Describe some challenges of implementing widespread Telehealth technologies

Core Content

Health Information Systems and Applications

- Types of functions offered by systems
- Types of settings where systems are used
- Electronic health/medical records systems as the foundational tool
- Telemedicine

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Key Terms

- Electronic Health Record
- Electronic Medical Record
- Health Information Systems
- Hospital Information Systems
- Knowledge Based Systems
- Personal Health Record
- Structured Data
- Telehealth Systems
- Telemedicine
- Unstructured Data

Clinical Vignette

A patient is hospitalized for new onset diabetic ketoacidosis. Upon discharge, the hospitalist sends a summary of the patient's hospital encounter to the patient's primary care physician (PCP). The patient calls the PCP's office to make an appointment. The office staff collects the patient's demographic and billing information and enters it into the electronic medical record (EMR). The patient goes to their appointment with the PCP who documents the visit in an EMR and orders a new medication. While using the EMR the PCP sees an alert that reminds them to check renal function and as a result orders the appropriate laboratory tests. After a week, the PCP has a virtual visit with the patient. The PCP asks the patient how they are tolerating the medication changes and reviews the results of the lab tests.

Introduction

This chapter explores the concept of a health information system and the components that comprise it. The term 'health information system' means many things to many stakeholders; where a critical care nurse may consider the system to be an order entry and documentation application, a financial analyst may consider the system to be a series of codes and interactions with other financial systems. First, there will be a consideration of the perspectives of these systems – who are the users of health information systems? What must the system accomplish in order to fulfill their needs? How does that impact the type and use of data? With these perspectives considered this chapter will review the applications that together comprise a health information system, including personal health records (PHRs), hospital information systems, telemedicine and telehealth systems.

Perspectives of Health Information Systems

In 2008, the World Health Organization set out the following definition of a health information system. "The health information system provides the underpinnings for decision-making and has four key functions: data generation, compilation, analysis and synthesis, and communication and use. The health information system collects data from the health sector and other relevant sectors, analyses the data and ensures their overall quality, relevance and timeliness, and converts data into information for health-related decision-making [1]".

The clinical vignette illustrates some of the stakeholders in health interactions: the patient, the hospitalist, the primary care physician, and office staff. Applying the key functions of the definition above, consider the viewpoint of each of these stakeholders. What role does the patient have in data generation? From a clinician's perspective, the patient is the source of the majority of information. He or she relates the history that the clinician captures, and it is their examination that the clinician performs. The patient may have a role in compiling data as well, such as retrieving the results of previous laboratory or imaging studies for analysis; and may also have a role in analyzing their data. Radermacher et al. have stipulated that a patient's preferences are weighed in conjunction with scientific evidence, a clinician's experience and judgment, and clinical circumstances to comprise the process of clinical decision making [2]. Finally, the patient has an integral role in the use of the clinical information, for ultimately it is their behavior that may need to change for the entire interaction to be successful.

Consideration of other perspectives are left as an exercise for the student but offer one additional consideration – the stakeholders listed above are a fraction of the total stakeholders of the health information system. Consider a hospital system and many others are identified: imaging technicians, physical therapists, speech and language pathologists, consulting physicians, health information management personnel, revenue cycle personnel, and administrators are examples. The complexity is compounded when one considers the various settings where each of these stakeholders may use a health information system. The needs of a nurse in an ambulatory clinic vary from those working in a surgical center, an emergency room, or a psychiatric unit. For a health information system to be successful, it must support at least these four key functions for all of its stakeholders.

Information Perspective

In the consideration of a health information system it is useful to divide data into two categories – that which relates to a particular individual patient and that which does not. The first set of data is defined as patient-specific information. The latter set can be construed as data derived from other sources of knowledge, be it a categorization of all known medical diagnoses or a list of postal codes in a given region.

Summarily, the second set of data is termed knowledge-based information. Knowledge-based information may apply to one or many patients. Take the example of a medication in a health information system. Information available on the medication itself in the system may include its name, any aliases, common prescription information such as dosages and frequencies, and perhaps even availability or cost. Many patients may be taking the same medication, but each patient has their own prescription for the medication with the dosage and frequency specific to them. This concept of patient-specific information versus knowledge-based information is reflected in the design of most medical record systems. In general, there will be a database of all known or relevant medications stored in a single location, with applicable pointers placed in the charts of all patients who are prescribed one of these medications.

Functional Perspective

The consideration of the information stored in a health information system is aided by another distinction – the intended use of the data. Clinical data can be defined as data collected with the intent of driving medical care. A clinician's examination findings, laboratory results, diagnostic imaging reports, and recordings of vital signs are all examples of clinical data. The volume of clinical data changes based on the context of the encounter: while a single set of vital signs may suffice for an entire outpatient encounter, such data may be recorded once a minute or more frequently in critical care settings. In contrast, we can consider administrative data to be that which is collected to support managerial functions. Examples of these functions may be seen in Table. 10.1.

The distinction between these two types of data is not always clear. For example, clinicians may capture a patient's weight at each visit to drive decision making regarding diet and exercise counseling; but a municipality might reuse aggregate measures of weights to drive decision making around where to create additional public recreation spaces. As reuse of clinical data increases, there has been increasing pressure on clinicians to capture data that may not be needed for the individual patient sitting in front of the clinician. For example, under the Meaningful Use program from the U.S. Centers for Medicare and Medicaid Services (CMS) that incentivizes the adoption and use of health information systems, surgeons are required to capture a patient's height during a postoperative surgical follow up visit,

Table. 10.1 Common managerial functions

Utilization review
Coding analysis
Clinical research
Public health registries
Quality initiatives
Vital statistics
Data warehouses

despite it having no clinical significance [3]. Another example is the recent recommendations from the Institute of Medicine that health care providers use information systems to capture data on the social determinants of health, including occupational, educational, and socioeconomic information on patients [4].

Composition of Data

A third distinction useful in the consideration of data stored in any information system is how that data is stored. Structured information is that which is stored as discrete data points such as gender, age, name, items in a review of systems, physical exam, and so forth. Unstructured data is information that is stored in aggregate. A common clinical example is free-text narratives, such as a clinician's record of a patient's presenting history, the 'history of present illness'; or their intentions in the management of a patient's health, the 'assessment and plan'. Structured data is generally much more easily used and reused but comes at the cost of increased cognitive burden in its capture.

Returning to our previous example of a medication prescription. To complete this in a structured system, a clinician might have to:

(a) Search for and select the correct medication;
(b) Enter the dosage desired;
(c) Enter the frequency desired; and
(d) Enter any specific patient instructions or parameters.

This can be contrasted with free text writing 'metoprolol 25 mg PO qday for HTN'. While this unstructured example takes advantage of several shorthands common in clinical practice, it is done for illustrative purposes. Consider now a desire to search for a cohort of patients who have an active prescription for hypertension. In a system of structured data elements, one could simply query the clinical parameters field for diagnoses relevant to hypertension. In a system of unstructured data elements, this analysis would require either manual chart abstraction or complex analytical approaches.

It should be noted that both structured and unstructured data are the foci of active research in informatics. Natural language processing aims to use machine learning algorithms to discretize unstructured data (see Chap. 9). Advents in human-computer interactions aim to make clinically relevant forms available in convenient form factors at a clinician's fingertips during a clinical encounter, thus overcoming much of the cognitive burden in the capture of structured information (see Chap. 13).

Applications of Health Information Systems

When considered in sum, a Health Information System should meet the needs of all participants interacting with the system. To complete this task, systems are comprised of multiple applications working in concert. These are described below.

Electronic Health Records

There has been some debate as to the distinction between electronic health records (EHRs) and EMRs. For the purposes of this chapter the definitions of the United States Office of National Coordinator for Health Information Technology are used. They state: *An EMR contains the standard medical and clinical data gathered in one provider's office. Electronic health records (EHRs) go beyond the data collected in the provider's office and include a more comprehensive patient history* [5]. In other words, an EMR contains all functionality necessary for a provider to store and retrieve their own information about a patient. An EHR expands this by incorporating and contributing to external data sources.

As the healthcare landscape has evolved in the United States over the past several decades, so too has its EHRs. Originally, medical records in the United States were developed as tools for a single department or use – repositories of patient demographics, laboratory information systems, and so on. With the advent of initiatives such as Patient Centered Medical Homes, EHRs are expanding to take on multiple roles. The most recent certification criteria for EHRs in the United States, the ONC 2014 Edition EHR Certification Criteria [6], postulates that an EHR may be comprised of one or more systems that in concert offer a set of functionality.

Core Functions of the Electronic Health Record

The Institute of Medicine defines the eight core functionalities of an EHR [7] as:

- Health information and data
- Result management
- Order management
- Decision support
- Electronic communication and connectivity
- Patient support
- Administrative processes and reporting
- Reporting and population health.

Health Information and Data Storage – Health information and data storage is an EHR's fundamental capability to store the clinical data regarding a patient's health care. Medical and nursing diagnoses, a medication list, allergies, demographics, clinical narratives, and laboratory test results are examples of data points that can be considered in the set relevant to an EHR.

Results Management – Results Management is an EHR's capability to store data gleaned from clinical procedures. Laboratory studies, radiographic investigations, and consultation reports are examples of such.

Order Management – Order Management and Order Entry are terms used to describe an EHR's capability to capture and facilitate clinical directives in the context of the provision of health care. A common variant is an order entry method that directly captures medical orders from providers; this is known as 'computerized provider order entry' or CPOE.

Decision Support – An EHR's capability to aid clinical judgment is Decision Support. Decision support may be context-specific, such as procedure specific documentation templates or drug-drug interaction alerts; or not, such as antibiograms.

Electronic Communication and Connectivity – EHRs may support direct exchange of data with end users (Electronic Communication) or other systems (Electronic Connectivity). For more details on Electronic Connectivity (see Chap. 11). Common examples of electronic communication include electronic mail or web interfaces.

Patient Support – Any process by which an EHR directly interacts with a patient to support the provision of care can be considered Patient Support. Examples include appointment and medication reminders.

Administrative Processes and Reporting – EHRs may support administrative processes such as appointment scheduling or billing. They may also generate reports that facilitate the administration of health care, such as service utilization rates.

Reporting and Population Health – EHRs may have capabilities to support the management of the health of a population. Examples include a report of a provider's patients that meet a standard of care, or contribution to a health department's disease registry.

EHRs may offer additional tools to augment one or more of the core functions described above. Some examples:

- The ability to verify a medication is being administered to the right patient at the right time can be augmented by real-time scanning of a barcode.
- Specialized communication functions may exist for creating and dispersing on-call schedules and patient handoff reports.
- Dashboards may collect and present quality metrics using a method with a lower cognitive burden for clinicians.
- Billing modules may collate and communicate subsets of clinical information to external stakeholders and systems.

The Healthcare Information and Management Systems Society (HIMSS) has developed a model for tracking progress of implementing various functions of a health information systems at a given health care institution (See Table. 10.2) [8]. The model consists of eight stages numbered zero to seven, beginning with implementation of laboratory, radiology, and pharmacy information systems and culminating with advanced communications between health information systems.

Two functions of the health information system have been the subject of more intense research – Health Information and Data Storage, and Order Management. This focus may be due to the greater proportion of time health care providers tend to spend on these functions. As a result, we too shall examine these in greater detail.

Recall from the earlier discussion that data stored in an information system may be captured in either structured or unstructured format. These same principles apply to the capture of health information. A physician may use a specific template to capture the results of an endoscopic examination and then dictate an operative

Table. 10.2 HIMSS EMR adoption model

Stage	Cumulative capabilities
Stage 0	Some automation. Laboratory, Radiology, Pharmacy Ancillaries not all installed.
Stage 1	Laboratory, Radiology, Pharmacy Ancillaries all installed.
Stage 2	Central Data Repository; Controlled Medical Vocabulary; Clinical Decision Support (CDS); may have document imaging; may have health information exchange capabilities.
Stage 3	Nursing/clinical documentation; CDS with error checking; Picture archiving and communication system (PACS) available outside of radiology.
Stage 4	Computerized provider entry; CDS with clinical protocols.
Stage 5	Closed looped medication administration.
Stage 6	Physician documentation; CDS with variance and compliance capability; full radiology PACS systems.
Stage 7	Full electronic medical record; clinical care document transactions to share data; data warehousing; data continuity with emergency departments, ambulatory and outpatient areas.

Adapted from [8] with permission from HIMSS Analytics

report of the same procedure. Regardless of method, Rosenbloom et al. [9] noted that four factors influence satisfaction with electronic documentation tools: efficiency, availability/accessibility, expressivity, and quality.

There are ongoing issues with electronic clinical documentation such as increased time spent by providers entering clinical data for documentation. Where before providers may have spent around 4 min documenting on paper, they spend upwards of 15 documenting electronically. The notes on paper were concise and now, they may contain many pages of laboratory data, diagnostic imaging reports and detailed dispensing instructions for medication lists. This extraneous data makes electronic clinical documentation difficult to understand. Electronic clinical documentation also introduces the issue of copying and pasting where sections of notes are copied and pasted from one day to the next. The risk of copying and pasting clinical data is that it may be incorrect or internally inconsistent within the note thereby making the clinical note difficult to understand. Because electronic clinical documentation can be bogged down with extra data, clinical notes are difficult to read and in many cases, not read at all. Information that is captured in clinical documentation not only serves to convey clinical meaning between providers, it also is being reused for other purposes including billing/insurance purposes, compliance, quality initiatives and public health. Front line providers are burdened with entering data into clinical encounters that they would not have done previously because of this secondary reuse of data [10].

New errors arise in electronic clinical documentation including documenting on the wrong patient or on the wrong encounter (documenting on an office visit when the patient is hospitalized), failing to save a note and the note is lost, notes that are labeled as the wrong note type (History and Physical labeled as a Progress Note).

Correcting these types of documentation errors is more challenging in the digital age than it was on paper [11].

The fidelity of data stored in health information systems has been of particular concern, especially as providers may incorrectly use tools such as 'Copy and Paste' to meet documentation requirements. In 2003, Hammond et al. [12] presented findings from the US Department of Veterans Affairs analysis of the prevalence of copying and pasting in progress notes. They created a severity scale ranging from 1–6, where one was of no risk and six of major risk. In their analysis, they noted that 9 % of notes studied contained copied or duplicated text, while one in ten electronic charts contained an instance of high risk copying.

Perhaps no function of the health information system has been as heavily researched as computerized provider order entry. Studies such as Bates et al. [13] have found that CPOE reduces errors, but others such as Han et al. [14] found an increase in mortality after implementing such systems. Both studies have undergone subsequent re-analysis and reinterpretation. In 2003, Payne et al. [15] presented the rationale for order sets – compilations of orders commonly generated as part of a single workflow. The rationale presented suggests that order sets reduce time to enter orders, reduces errors and increase accuracy, increase completeness, and provide a platform to enforce decision support and application of best practices. However he found that at 6 months after creation of order sets, only 13 % had been used. Ash et al. [16] conducted a telephone survey in 2007 to assess the extent of unintended consequences of CPOE workflows. The survey suggests that implementation of CPOE may alter the underlying workflow of order management with new issues specific to these new workflows.

Derivative Systems of an EHR

As previously discussed, the health information system may be comprised of one or more systems acting in concert to provide a spectrum of functions. While the EHR is a common source of data in the health information system, the analysis of that data and presentation of subsequently generated information is not limited to the EHR. One or more derivative systems may exist, which can be defined as those systems that extract information from an EHR for the purpose of subsequent analysis and information synthesis. Such systems need not draw from the EHR alone, they may draw from data warehouses, which are central repositories of integrated data from one or more disparate sources. Such warehouses may include quality survey data or billing data and allow for analysis not possible with a single information source. One example of this was the Observational Medical Outcomes Partnership, as described by Stang et al. [17] Other systems exist that draw information from multiple health information systems. Registries, or collections of information about individuals usually focused around a specific disease or condition, are an example of this type of system [18].

Practice Management Systems

In the 1980s and 1990s, healthcare providers would generally install a practice management system alongside an EMR. While the EMR contained all the information relevant to the provision of healthcare, practice management systems provided the functions necessary to support the business of healthcare – scheduling appointments, registering patients, submitting claims for payment, and so on. Similar to other areas of the health information system, one or more systems may act in concert to provide a practice management solution. As with the evolution of EMRs previously mentioned, practice management systems have been increasingly integrated into the health information system. Such integrations feature advantages such as a single database of patients and integrated billing workflows.

Personal Health Records

In other areas of informatics, the consumer has become increasingly involved with the information system. Demos et al. [19] cite a trend of eroding manual transactions in the United States in the context of the banking industry. While interpersonal interactions are at the heart of most healthcare workflows, many routine transactions, such as requesting medication refills, could be managed through more automated processes.

While such transactions may be supported through the provision of a patient portal, these are to be held distinct from PHRs. Patient portals provide a window for patients to directly access the EHR. Through such windows patients may accomplish functions as allowed by the healthcare institution, and may include refill and appointment requests. In contrast, PHRs are used by patients to maintain and manage their own health information. These are currently held separate from the legal record of health care providers in the United States. Just as with other aspects of the health information system, PHRs may also incorporate data from multiple sources [20].

Hospital Information Systems

The needs of a hospital are specific enough that many apply the term 'hospital information system' to a health information system tailored to these needs. As with other health information systems, the hospital information system is often comprised of several systems working in concert to provide the necessary functions to all its stakeholders. Some of these functions are seen in Table. 10.3.

Table. 10.3 Hospital information systems

Admission, discharge, and transfer (ADT) systems	Laboratory Information System (LIS) {e.g. Sunqest, ApolloLIMS}	Nutrition and Dietary Management Systems
Patient registration systems	Radiology Information System (RIS) {e.g. GE Centricity PACS, McKesson Horizon Medical Imaging}	Specialized systems for common procedures (such as pulmonary function testing, echocardiography, endoscopy)
Master patient index	Picture Archiving and Communications System (PACS)	Specialized systems for medical specialties such as obstetrics, ophthalmology, dermatology, anesthesia, or oncology
Inventory/Materials and Supply Chain management {e.g. Omnicell, Pyxis}	Pharmacy Systems	Infection Control management systems
Systems to collect and report quality or administrative metrics	Anatomic Pathology Systems	Professional and Hospital billing systems

Knowledge Based Systems

Knowledge based systems are those which apply previously compiled information to solve complex problems. While there are many such systems, they commonly attempt to represent knowledge explicitly, via constructs such as ontologies and rules, rather than implicitly, such as in computer code. Some examples common to health information systems include:

- Information Retrieval Systems – systems that index information available from other sources for facilitated querying and retrieval.
- Decision Support Systems – systems that analyze patterns in health data and present information intended to influence the behavior of healthcare providers (see Chap. 6).
- Question-Answering Systems – systems that allow querying, generally in natural language, and present facts pertinent to the inquiry.

Telemedicine and Telehealth Systems

Any system that facilitates the provision of healthcare where the patient and the provider are in disparate geographic locations can be considered a telemedicine or telehealth system. While the simplest modern example is telephonic systems, technology is available to include other information streams such as photographic and videographic systems, remote health monitoring systems, and more.

There are important challenges to overcome before telemedicine is widely adopted, including third-party reimbursement issues and cross-state medical licensure of providers. Given these, modern applications are generally limited to situations where it is impractical to have a direct patient-provider interaction. For example, teledermatology and remote critical care systems are being used when providers are in limited supply; remote home monitoring is being used when there are geographic or transportation-related barriers. Because of lower financial barriers and lack of need for a direct patient-provider interaction, teleradiology is currently one of the most common telemedical applications.

One example of using telehealth to replace in person care is with the work that Kaiser Permanente is doing [21]. A third party vendor provides videoconferencing capability that is integrated into Kaiser's EHR. Patients make appointments online for 20 min visits with a provider. For the appointment the patient logs into the patient portal to have a video conference visit with the provider. If the provider encounters a need that cannot be provided through the videoconference, such as listening to the lungs or checking blood pressure, the patient is referred to a care center for an in person visit.

The Veteran's Administration is an active user of telemedicine to provide primary care services to rural areas and to expand their ability to provide mental health care [22]. Patients come into the clinic to visit with their mental health provider, but also have virtual meetings in between scheduled appointments to provide ongoing support.

Summary

The nature of health IT takes on multiple definitions given the complexity and variety of stakeholders and their requirements of the system.

Questions for Discussion

- What are some of the ways that Electronic Medical Records perform Decision Support?
- What are the common functionalities of an EHR?
- What is the ideal way to capture data from providers? In a structured or an unstructured format?
- What are the ways that clinical data is used?
- Who are the various stakeholders who need the information within an EHR?

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