Abstract
Healthcare information technologies (HITs) encompass a growing range of data collection, processing, and analyzing devices and procedures. The healthcare industry in general is a highly regulated field, and at times agencies impose regulations on healthcare technology and data use can conflict with each other as well as with healthcare and computer industry standards. The field of HIT emerged slowly beginning in the 1960s, but advances in computer technology and declines in technology costs accelerated growth. Technologies include electronic health records, e-prescribing, computerized physician order entry, and clinical decision support systems. Beyond use for data storage and analysis are technologies such as radiological scans, robotics, and lasers, which use data to deliver healthcare services. Big data plays a growing role in the HIT area, and data governance gains importance due to the need to ensure accurate and secure data on demand.

INTRODUCTION
The article covers the growing field of healthcare information technology (HIT). Healthcare professionals use HIT extensively in providing services to patients. Hospital workers, primary care physicians, pharmaceutical researchers, and medical insurance providers are using HIT in a growing number of ways. HIT first emerged in the 1960s with the creation of electronic health record (EHR) systems. Concurrent with the establishment of the first EHR systems was the development of standards for the systems to ensure safe and effective use. Further uses of HIT including personal health records (PHR), computerization physician order entry (CPOE), and clinical decision support systems (CDSS) developed as computer use increased and technology costs declined. As the use of HIT evolved, government regulation and further standardization arose to provide a framework for usage. Healthcare professionals now use HIT in the fields of radiology, surgery, and public health; the technologies range from computers to handheld scanners to robotics to environmental sensors.

HISTORY OF HEALTH INFORMATION TECHNOLOGY
The development of first health information systems occurred in the 1960s. Early projects included a health information system at LDS Hospital in Utah, the Computer Stored Ambulatory Record System at Massachusetts General Hospital, the Regenstrief Medical Record System, the Department of Defense’s Composite Health Care System, and the Veteran’s Administration’s De-Centralized Hospital Computer Program. Concurrent with the development of EHR systems, the World Health Organization began promoting healthcare doctrine worldwide. The International Classification of Diseases (ICD) program started an international disease tracking system. The American Medical Association developed the Current Procedural Terminology (CPT) to describe surgical procedures following the ICD system. The ICD and CPT coding systems expanded to all categories of health maintenance, enabling a standard EHR system. The development of the Uniform Billing System made a reimbursement system for medical claims possible using the EHR.

The twofold goal of health information systems was an improvement of clinical decisions and reduction of medical errors. However, use of the technology was limited due to reluctance of physicians to use slow, expensive, unproven technologies, the reticence of administrators to invest in technology with no financial advantage, and lack of integration of the technology with hospital systems in general. The situation began to change in the 1980s with advances in computer technology that led to reduction in computing costs, introduction of large-scale microcomputer networking, and the development of data interchange protocols. Since the 1980s, the emergence of Internet technologies has spurred the growth of HIT. Many countries have adopted national healthcare systems. Healthcare professionals have grown more accustomed to using technology on a daily basis and are thus less reluctant to use systems on the job.

The study “To Err is Human” published by the Institute of Medicine in 1999 motivated the public health professionals to action regarding HIT. The researchers
reported that as many as 98,000 people die each year in U.S. hospitals due to preventable mistakes, and recommended the use of EHR in part to remedy the problem. However, 10 years later the adoption rates of EHR systems were only 17% for physician’s offices and 12% for hospitals. Government regulation influenced greater adoption of HIT in general and EHR systems in particular.[2]

REGULATIONS

U.S. government intervention in the realm of HIT extends back to the enactment of the Health Insurance Portability and Accountability Act (HIPAA) of 1996. With HIPAA, legislators mandated security and privacy measures for healthcare information systems. The Medicare Modernization Act of 2003 requires a prescription drug benefit for Medicare beneficiaries (Part D) that depends upon the support of an electronic prescription program for providers and pharmacies voluntarily using computer systems for prescriptions. The Bush Administration stressed the necessity of interoperability of health information technology infrastructure in Executive Order 13335 in 2004 and promoted quality healthcare through the use of health information technology in Executive Order 13410 in 2006. Both the Patient Protection and Affordable Care Act of 2010 and Health Care and Education Reconciliation Act of 2010 stipulated the development of interoperability and security standards and protocols in federal and state health and human service program providers.[1]

The legislation with the greatest influence on recent adoption of EHR is the Health Information Technology for Economic and Clinical Health (HITECH) Act, which is part of the American Recovery and Reinvestment Act (ARRA) of 2009. The HITECH Act established the Office of the National Coordinator and charged the office with the development of a national HIT infrastructure. The HITECH Act emphasized the importance of information security and privacy as part of the infrastructure. The HITECH Act also authorized monetary provisions for EHR-related training and HIT improvements. In conjunction with the HITECH mandate, the ARRA set requirements for EHR adoption and use by healthcare providers.[1,4]

STANDARDS

HITs are subject to sometimes conflicting standards in healthcare and in technology. The Joint Commission, the Utilization Review Accreditation Commission (URAC), and the National Committee for Quality Assurance set healthcare-related standards. Standards development organizations including the Institute of Electrical and Electronics Engineers (IEEE), the American National Standards Institute (ANSI), the National Institute of Standards and Technology (NIST), and the World Wide Web Consortium (W3C) establish, examine, and revise technology standards. The Certification Commission for Health Information Technology and the Healthcare Information Technology Standards Panel influence standards specific to healthcare technologies. Major standards in the healthcare area are ICD, Health Level Seven (HL7), and Digital Imaging and Communication in Medicine (DICOM).[1,3]

The Joint Commission is an independent, not-for-profit organization responsible for the accreditation and certification of healthcare organizations and programs in the United States. The mission of URAC focuses on determining whether healthcare and related service functions are medically necessary. The National Committee for Quality Assurance uses many approaches, including surveys, audits, and clinical performance measurement to accredit, certify, or recognize healthcare organizations.[1]

The IEEE, ANSI, NIST, and W3C establish standards for all technology use. The most important technology standard is the Open-Systems Interconnection/Internet Protocol (OSI/IP), which affects transfer of data from one system to another and provides the basis for Internet communication. The protocol includes seven layers for communications: physical, data link, network, transport, session, presentation, and application. The physical layer deals with the characteristics of the local network. The data link layer involves transferring data node-to-node within the immediate subnet. The network layer routes data across all necessary subnets. The transport layer checks for data integrity and prepares the data for transfer to another network. The session layer establishes communication between two systems. The presentation layer encodes the data for ultimate display. The application layer is the user interface, which is the ultimate means of displaying the data.[3]

Healthcare data standards regulate both coding and communications. The ICD classification system extends back to the 1960s and 1970s, with the most current revision being ICD-10. The ICD classification system encompasses several terminology–vocabulary standards: Medicare Severity Diagnosis-Related Groups (MS-DRG), CPT, Logical Observation Identifiers Names and Codes (LOINC), Systematized Nomenclature of Medicine Reference Terminology (SNOMED), Clinical Care Classification (CCC), and International Classification of Primary Care (ICPC). The MS-DRG standard affects payment services and Medicare and Medicaid billing. The CPT contains standard procedure codes for reimbursement and billing. The LOINC identifies laboratory results and clinical observations. The SNOMED integrates data from multiprovider care processes through
mapping with other ICD coding standards. The CCC provides the framework for documenting holistically hospital-based patient care processes. The ICPC encompasses severity of illness checklists as well as functional status assessment charts.[3]

HL7, the standard related to management, processing, integration, and exchange of electronic healthcare data, receives its name from the OSI application layer (level 7). HL7 is currently the most widely implemented data-messaging standard in healthcare. Several core clinical standards are available through HL7 including order entry, scheduling, radiographic reports, and examination findings. HL7 establishes strategies to help healthcare agencies achieve compliance with its regulations:

1. HL7 will maintain the meaning and/or semantics of nomenclature of health-related knowledge and will promote the development of relevant and compatible standards that would support the efficient transfer and sharing of healthcare knowledge and information between computers.

2. It will evolve a formal methodology to support the creation of HL7 standards from the HL7 Reference Information Model.

3. It will disseminate information on the benefits of healthcare information standardization to academic institutions, healthcare management organizations, healthcare service providers, policy makers, and the public at large.

4. It will encourage the adoption and diffusion of HL7 standards worldwide through the efforts of HL7 international affiliate organizations, which will be formed to participate in developing and localizing HL7 standards.

5. It will bring together domain experts from academic institutions, healthcare service provider organizations, and healthcare management organizations to collaborate and develop standards for HL7 inclusion in various specialty areas.

6. HL7 will join with other Standards Development Organizations and national and international sanctioning bodies such as ANSI and International Organization for Standardization to promote the mutual exchange and use of compatible and other healthcare information standards.

7. HL7 will ensure that current propagate standards fulfill the diverse requirements of the present era and will initiate effort to meet the emergent requirements.

8. HL7 will institute membership policies to ensure that all requirements are met uniformly and equitably with quality and consistency.[5]

The DICOM standard addresses the transfer of digital images in a variety of formats between diverse devices and systems. The level of transferability bridges gaps in interoperability among different hardware systems and platforms. Healthcare areas that use DICOM standards include cardiology, dentistry, endoscopy, mammography, ophthalmology, orthopedics, pathology, radiation therapy, radiology, surgery, and even veterinary science. The DICOM standards committee has numerous working groups that concentrate efforts in five general application areas: network image management, network image interpretation management, network print management, imaging procedure management, and offline storage media management.[3]

TECHNOLOGIES

A number of computerized technologies exist in the health information area. Most HIT systems either interact with or act as part of an EHR system. Other forms of HIT include PHR, CPOE, CDSS, picture archiving and communication systems (PACS), regional health information organizations (RHIOs), and the Nationwide Health Information Network (NwHIN).

Electronic Health Records

Healthcare practitioners use EHR systems to collect, store, and retrieve patient data. The systems allow health information professionals to view patient data upon request, enter patient care orders, and receive advice in making healthcare decisions.[1] An EHR system seeks to improve healthcare provider access to all relevant patient health data enabling the diagnosis and treatment of both injuries and diseases.

Researchers classify EHR systems as either basic or comprehensive. Basic EHR systems have 10 clinical functions used in at least one hospital unit, while comprehensive EHR systems have 24 clinical functions used throughout all hospital units. Four groups of clinical functions are clinical documentation, test and imaging results, computerized provider-order entry, and decision support. Clinical documentation functions include physicians’ notes, nursing assessments, problem lists, medication lists, discharge summaries, demographic characteristics of patients, and advanced directives. Test and imaging results include laboratory reports, radiologic reports, radiologic images, diagnostic test results, diagnostic test images, and consultant reports. Computerized provider-order entry functions are laboratory tests, radiologic tests, medications, consultation requests, and nursing orders. Decision support functions include clinical guidelines, clinical reminders, drug allergy alerts, drug–drug interaction alerts, drug–laboratory interaction alerts, and drug–dose support.[5] Basic and comprehensive EHR systems are both able to meet all legislated requirements. While adoption of
comprehensive systems provides the greater benefits, the financial cost and time to implement greatly reduce the range of clinical systems a healthcare provider ultimately selects.

Lack of widespread EHR implementation motivated legislators to enact ARRA in 2009. The ARRA has best encouraged EHR system establishment through incentives, including the U.S. Department of Health and Human Services-sponsored Medicare and Medicaid Incentive Programs. The key provision of both incentive programs is documentation of meaningful use of an EHR system.

To document meaningful use, the programs designate required reporting objectives that include core objectives, nine menu objectives, and clinical quality measures (CQM). Healthcare providers must report all of the core objectives and five of the menu objectives; there is no specific threshold for reporting CQM. The core objectives are CPOE, drug–drug and drug–allergy checks, maintenance of an up-to-date problem list of current and active diagnoses, E-Prescribing (eRx), maintenance of an active medication list, maintenance of an active medication allergy list, maintenance of recording demographics, maintenance of recording and charting changes in vital signs, maintenance of recording of smoking status for patients 13 years or older, implementation of clinical decision support, provision to patients of the ability to view, download, or transmit their health information online, provision of clinical summaries for patients for each office visit, and protection of electronic health information.

The first two menu objectives are a submission of electronic data to immunization registries or the submission of electronic syndromic surveillance data to public health agencies; it is required that one of these two is fulfilled. The remaining menu objectives are drug formulary checks, incorporating of clinical lab test results, generation of lists of patients by specific conditions, sending reminders to patients for preventive follow-up care, use of patient-specific education resources, electronic access to health information for patients, medication reconciliation, and summary of care record for transitions of care. Two sets of CQM exist, one for adult patients (both Medicare and Medicaid) and one for pediatric patients (Medicaid only). The CQM for adults are controlling high blood pressure, use of high-risk medications in the elderly, preventive care and screening for tobacco use, screening and cessation intervention, use of imaging studies for low back pain, preventive care and screening (including screening for clinical depression) and developing related follow-up plan, documentation of current medications in the medical record, preventive care and screening including body mass index screening and follow-up, closing the referral loop through receipt of specialist reports, and functional status assessment for complex chronic conditions. The CQM for pediatric patients are appropriate testing for children with pharyngitis, weight assessment and counseling for nutrition and physical activity for children and adolescents, chlamydia screening for women, use of appropriate medications for asthma, childhood immunization status, appropriate treatment for children with upper respiratory infection, attention-deficit/hyperactivity disorder (ADHD) treatment notation including follow-up care for children prescribed ADHD medication, preventive care and screening and screening for clinical depression and follow-up plan, and notification of children who have dental decay or cavities. Each of the incentive programs had slightly different levels of reimbursement for EHR implementation. The Medicaid incentive program reimburses up to $63,700 and the Medicare incentive program reimburses up to $43,700. With the advent of ARRA and the meaningful use directives, EHR adoption became a necessity for healthcare practitioners. The mandated systems fulfill meaningful use reporting requirements but cause a major change in workflow. The goal of EHR implementation is to reduce medical errors. Increased legibility, access to information, and standardization of data entry and display are factors influencing the realization of the goal. The outcome of the goal is overall improvement in the healthcare system in the United States.

Increased revenue and avoided costs are two financial benefits of EHR adoption. One means of increasing revenue is the shortening of visit times due to more efficient records. Improvements in medical billing also increased revenue. Fewer rejected claims and more accurate coding of work performed generated the medical billing revenue increase. Avoidance of dictation and external billing are cost-avoidance benefits, as is staff reductions. Doctors are able to attend to more patients on any given day because of shortened visit time for each patient. Medical office staffs have the potential to work more efficiently; filing duties are greatly reduced if not eliminated.

Several obstacles need to be overcome before EHR systems maximize potential benefits. Even with existing incentive programs, cost and uncertainty of return on investment predominate as the main obstacles to EHR adoption. One study of physicians’ offices in Massachusetts indicated that of the survey respondents, only 27% experienced a positive return on investment over a 5-year period. Not all physicians’ offices experience all of the potential benefits; some actually have longer visits due to lack of physician or staff capability with the technology. Costs can be greater than anticipated and budgeted.

Lack of interoperability continues to be an issue with EHR systems. In 2012, 700 EHR vendors sold over 1,700 highly proprietary products. While coding standards exist to allow similarities in recording of medical data hardware or software, differences impede the
ability to share the data among different healthcare providers’ systems.

**Personal Health Record Systems**

PHR empower patients to play a more active role in their healthcare. Through the ability to view healthcare data, obtain referrals, schedule appointments, obtain prescription refills, and e-mail physicians using PHR, patients can be more active and knowledgeable participants in their healthcare. Researchers note that major capabilities of PHR systems include quality, completeness, depth, and accessibility of personal health data; better communication; better access to health knowledge; portability; and self-entry of data.\(^{[1]}\)

Major means of PHR implementation are stand-alone PHR, patient portals, and integrated PHR. Stand-alone PHR programs are home-use systems for patients that allow the patients to manually enter and organize their own data. Patient portals allow users to connect to their primary care physicians’ records for limited information. Integrated PHR systems use network or Internet connections to allow patients to directly log into health records systems of their primary physicians; some hospitals also have PHR systems integrated into the institution’s EHR system.\(^{[1]}\)

Stand-alone PHR programs, which include Dr. Koop, HealthCentral, and Revolution Health, have extremely limited capabilities. The stand-alone PHR programs do not have the ability to connect with physician records, so the onus falls entirely on the patient to maintain and update data.\(^{[1,3]}\) Potential inaccuracy of the data entered and lack of review by knowledgeable healthcare professionals impair the usefulness of stand-alone PHR programs.

Patient portals are a step further than stand-alone PHR programs in that portals allow the patient access to their primary care physician’s records. Patient portals, however, lack full integration; data comes only from the primary care physician’s office and does not incorporate tests or lab results from other sources. Some, however, have the ability to access personal health information from any of three hospitals and 72 ambulatory care facilities. Patients could also use the PatientSite system to update information including home glucometer readings, over-the-counter medications, and personal notes themselves. Indivo is a self-built, institution-neutral open-source personally controlled health record. A personally controlled health record is a subset of PHR in which a patient can personally controlled health record. A personally controlled health record is a subset of PHR in which a patient can designate who can read, write, or modify his or her own data in the record, screening and appointment alerts, and information about their health concerns.\(^{[1]}\)

Researchers have conducted studies of success of PHR systems including both vendor-created and institution-created integrated PHR systems. MyChart by Epic Systems is one vendor-created PHR system studied. The PHR system allows patients to view most of the contents of their medical records (except for progress notes), diagnoses, active medications, allergies, health maintenance schedules, immunizations, test results, radiology results, appointments, and demographics. The overall system provides improved patient–physician communication. The PatientSite system at Beth Israel Deaconess Medical Center is a self-built system which provides patients full access to problem lists, medications, allergies, visits, laboratory results, results of diagnostic tests, and microbiology results as well as the ability to access personal health information from any of three hospitals and 72 ambulatory care facilities. Patients could also use the PatientSite system to update information including home glucometer readings, over-the-counter medications, and personal notes themselves.
way to improve intervention planning and patient education.[10] Improved patient–physician relationships and better patient education promotes a higher level of patient empowerment in healthcare.

Challenges with PHR implementation stem from patient concerns regarding privacy and security of data and lack of technical standards. Interoperability remains an issue with PHR for the same reasons cited in the EHR section. Important hurdles include the authentication of the user (ensuring that the person attempting to access the data is indeed the patient), integration of Internet knowledge sources, and security of messaging.[1] Technical standardization of PHR and EHR systems can mitigate the challenges cited.

**eRx Systems**

The Medicare Modernization Act of 2003 provided a major stimulus for increased use of electronic prescribing (eRx) systems. eRx systems can either be stand-alone or integrated, where the stand-alone systems support only eRx and integrated systems are part of a comprehensive EHR system. Due to the incorporation into EHR systems, the integrated systems predominate. Five major functions performed using eRx systems are computerized prescribing associated with clinical decision support, pharmacy benefit eligibility checking, formulary compliance, medical history reporting, and prescription routing to the pharmacy.[1] When a healthcare provider enters a prescription into an eRx system, the system records the prescription and checks against both the diagnosis and patient history, including other current prescriptions. The checks reduce the possibility of adverse drug events (ADEs), which are basically side effects of a prescription due to interaction with another prescription or incorrect dosage. Once checks of the prescription are complete, the system sends prescription electronically to the patient’s pharmacy. The transmission of an electronically prepared prescription reduces the pharmacy’s need to check patient prescription plan eligibility or to call to verify the prescription due to illegible handwriting.

Patient safety is the primary benefit of eRx systems.[1] The functions of the system ensure fewer adverse drug interactions and pharmacy fulfillment errors. The entire prescribing process is more efficient, with both reconciliation of prescriptions being quicker to perform and reduction of a pharmacist’s time and effort spent on difficult-to-read prescriptions.

A number of barriers to implementation exist for eRx systems. The barriers include the need to overcome previous negative technology experiences, initial and long range costs, lost productivity at implementation time, competing priorities, change management issues, confusion about competing products, information technology requirements, interoperability limitations, and standards limitations.[11] However, with the mandate to install eRx systems and the incentives to do so in conjunction with EHR systems, the benefits realized reduce the impact of the barriers. Upon full implementation of eRx systems few problems were noted.

**Computerized Physician Order Entry Systems**

CPOE systems are often a subset of EHR systems. The ARRA makes CPOE system activity a requirement of EHR systems in order to fulfill meaningful use criteria. A CPOE system allows the physician to enter medication, diagnostic testing, and ancillary service orders.[1,11]

Benefits of CPOE include increased efficiency through use of medication and lab ordering functionality, potential reduction in medication errors and ADEs, and improvement in the quality of prescribing. Of particular importance is the reduction of ADEs. Most preventable ADEs result from errors at the physician ordering stage. System efficiencies as well as the elimination of problems resulting from both illegible writing and lack of structure generate the benefits of the systems. Overall the benefits improve patient care and safety.[11–13] The use of CPOE standardizes the entry of physician orders. The standardization improves understandability due to better and more uniform structure. Since many medications have names that differ by a few letters, or have long names that physicians abbreviate, handwritten prescribing was a major threat to patient safety. Ready access to data about both drug interactions and adverse effects within the system provides the physician better information to make an informed decision about medication.

Safety issues attributed to CPOE systems are a major concern. A study divided safety issues related to CPOE into five distinct areas: people, process, organization, environment, and technology. Safety issues in the people area involve the user’s lack of clinical knowledge or technical expertise, level of critical thinking ability, or negative emotions arising from using the system. Safety issues arising from process relate to the change in communication patterns and workflow that occur when adopting CPOE. Changes in power structure and organizational culture resulting from CPOE adoption are organizational safety issues. Distractions in the work environment were the main environmental issue. Inherit technology problems, such as data entry failures and crashes, are the final class of issues.[14]

Other barriers exist to the adoption of CPOE. High installation and operating costs, disruptions to operating procedures, organizational and clinical work practice issues, and uncertainty about governmental requirements related to HIT are major issues. Also, several researchers fear that a rush to adopt CPOE could adversely affect
the quality of the design and implementation of the system, thus negating the system’s benefits.\(^\text{[12]}\) Healthcare providers need to treat CPOE technology adoption as a major undertaking. Fast-tracking installation can lead to poor system quality decreasing physician use and thus reducing the benefit of the system overall.

### Clinical Decision Support Systems

CDSS aid healthcare professionals in a clinical setting with evaluating decisions. Typical decisions made with the use of CDSS include decisions regarding patient transfer to or from an intensive care unit, use of ventilation and drugs, and discharge home or to a skilled nursing facility. While CDSS can be nonknowledge based with use of machine learning and statistical pattern recognition, typical systems are knowledge based. Knowledge-based CDSS are comprised of a knowledge base, an inference engine, and a user interface. The knowledge base contains information gathered from healthcare professionals formatted as if–then rules. The inference engine combines the necessary rules from the knowledge base with the patient data. The CDSS enables capture as well as reuse of clinical data and optimization of problem solving and decision making.\(^\text{[1]}\)

Different benefits of CDSS emerge from system use by different clinical users. Studies found that nurses and doctors use the systems differently, with nurses using system-generated information to strengthen their patient advocacy position in coordinating care with physicians whereas physicians use the systems to compare with their own clinical judgment.\(^\text{[1]}\) Nurses provide direct care for the patients and are able to observe the patients more closely. Based upon their own observations and CDSS use, nurses can raise concerns to the doctors, thus improving patient care. Doctors supplement their own knowledge with the information the CDSS provides. The CDSS output may offer the doctor alternative diagnoses or offer new treatment methodologies.

Some safety issues exist with the use of CDSS. The safety issues include false expectations of the system or incorrect perception of accuracy, deficit of either clinical knowledge or clinical judgment on part of the user, missing data, and lack of patient-specific decision support.\(^\text{[1]}\) Users can become over-reliant upon the CDSS or use the system to rush decisions. When creating the knowledge base, developers could fail to enter important information into the system due to carelessness or misjudgment, rendering the CDSS output less than optimal or even wholly incorrect. Combinations of conditions of a specific patient may not be available in the knowledge base, also making the decision less accurate.

### Regional Health Information Organizations

RHIOs are local groups of physicians’ offices, hospitals, health insurance providers, employers, pharmacies, consumer groups, and government officials that work together to establish a local infrastructure for HIT interoperability.\(^\text{[1]}\) Members of an RHIO meet to agree upon standards and technology that all members will adopt. Use of common standards and technologies enable interoperability of the systems. While a trade-off of less freedom of choice in system adoption exists, the benefit of interoperability outweighs the cost.

The Massachusetts eHealth Collaborative (MAeHC) provides an instructive example of an RHIO. Members of the MAeHC agreed on a standard architecture and a limited number of vendors. Factors determining the architecture and vendors include security, cost, implementation complexity, performance, measurement of quality of care, strategic goals, trust in the medical community, and the stakeholders’ desire for independence. The participants enjoyed the benefits of increased quality, safety, and efficiency in the regional system. However, members found barriers during the implementation of the RHIO that included inadequate standards for data representation and vocabulary, vendor and system obsolescence concerns, and privacy and security issues.\(^\text{[1]}\) Even so, a recent survey of participants in the MAeHC found that just over a quarter of the respondents experienced a 5-year return on investment on the technology expenditure.\(^\text{[10]}\)

### Nationwide Health Information Network

The NwHIN is the proposed infrastructure for sharing health data across the United States. The Office of the National Coordinator of Health Information (ONC) established the initial plan for the infrastructure during the Bush Administration. The ONC proposed a model with a network of health information organizations exchanging data with other such organizations. The plan was essentially a decentralized network, possibly built of RHIOs. However the ONC now recommends a centralized, point-to-point information exchange enabled by Internet technologies.\(^\text{[1,15]}\) Change in staffing in the ONC during the Obama Administration likely caused the change in strategy.

At this point, politicians and healthcare practitioners debate the infrastructure of the NwHIN. Advantages and disadvantages exist under both a decentralized RHIO-based infrastructure and the centralized Internet-based counterpart. The RHIO-based infrastructure could potentially optimize existing resources while preserving local autonomy. The functions of RHIOs depend on the community’s need and RHIOs serving the need through health information exchange across the community. The
RHIO model is difficult to sustain due to lack of return on investment and funding cuts under the Obama Administration. Most other countries with health information sharing infrastructures have adopted models that are consistent with the centralized architecture. However, current technology makes implementation at the nationwide scale impractical. Further examination of infrastructure options and technologies could result in a compromise between the proponents of each model or creation of a radically different model as new technologies develop.

OTHER IMPLEMENTATIONS OF HEALTH INFORMATION TECHNOLOGIES

Health information technology encompasses more than the storage and transmission of patient health information. A wide range of technologies exist to aid in diagnostic and surgical procedures. Technologies allow practitioners to perform new procedures and to process data in new ways that lead to improvements in public health.

Radiology

Several health information technologies exist in the field of radiology. The older technologies in the field are x-ray and ultrasound, and newer computer-aided technologies include computed tomography (CT) scan, magnetic resonance imaging (MRI), single-photon emission computed tomography (SPECT) scan, positron emission tomography (PET) scan, and dual x-ray absorptiometry (DEXA) scan. Computer-aided detection capabilities integrated into the technologies allow users to automatically read the scan. In addition to these diagnostic technologies, PACS enable electronic storage and communication of scans and tests.

x-Ray technology has evolved in recent years with the introduction of digital x-rays. One advantage of digital x-rays is that technicians do not need to develop the images, so images are available immediately for viewing and sharing. Additionally, practitioners can easily share the digital images over a network for consultation, and several consulting healthcare professionals can view the images simultaneously in consultation. Users can enhance, highlight, and resize digital x-ray images; technologists are exploring the concept of three-dimensional digital x-rays based upon multiple images. Digital x-rays also use less radiation than traditional x-rays, making the process safer for patients and practitioners. Healthcare workers use x-rays prevalently in cases of broken bones and in the fields of dentistry and mammography.

Ultrasound makes use of high-frequency sound waves and the echoes produced when the waves hit an object. Computer technology has enhanced ultrasound technology by enabling users to view two-dimensional moving pictures onscreen during the imaging. Surgeons use three-dimensional ultrasonic endoscopes for minimally invasive surgery. Uses of ultrasound extend from the study of blood flow to treatment of prostate disease and diagnosis of breast cancer.

Health information technologies that are specifically based upon digital imaging techniques include CT scans, MRIs, PET scans, SPECT scans, and DEXA scans. CT scans incorporate the use of x-rays and digital technology in the generation of cross-sectional images of a patient’s body. Exams using CT scans can contain thousands of images and are better than x-rays alone alone in distinguishing soft tissue. Practitioners also use CT scans to locate nerve centers when dealing with pain. Enhanced CT scans use special dyes to aid in diagnosing brain tumors. Virtual cystoscopy and colonoscopy use CT scans and reduce the need for invasive surgery.

The scientific visualization technique in MRI enables the MRI machines to use computers combined with strong magnetic fields and radio waves to produce images from mathematically generated data. The images are accurate pictures of body or brain structures aiding in the diagnosis of strokes, brain tumors, and multiple sclerosis. Practitioners use functional MRIs (fMRIs) to identify brain activity through the measurement of metabolic changes in active parts of the brain. The fMRI aids in the diagnosis and treatment of strokes, brain tumors, and other brain injuries. Neurosurgeons use the MRI technique of diffusion tensor imaging as a surgical aid.

Healthcare professionals use radioisotope technology in PET scans to create images of the body in action. Computers construct images from the positive electrons (positrons) emitted by radioactive substances technicians administer to patients prior to testing. The images a PET scan produces show how the body works rather than how it looks. Doctors use PET scans to detect changes in cell function that indicate conditions such as Alzheimer’s disease, Parkinson’s disease, epilepsy, learning disabilities, bipolar disorder, and cancer. Neuroimaging techniques show the chemical and physiological processes taking place in the brain, allowing doctors to diagnose schizophrenia, major depression, post-traumatic stress disorder, and obsessive-compulsive disorder. Single-photon emission computer tomography scans are similar to PET scans, but the equipment is less expensive. The SPECT scan uses gamma radiation in image creation. Doctors can diagnose osteoporosis through the use of DEXA scans, which use low-radiation x-rays to show changes in intensity after passing
through bone, which indicate changes in bone density.\textsuperscript{[16]}

A PACS is an electronic system to acquire, store, display, and transmit medical images. The PACS allows users to quickly and easily share images with authorized practitioners through the use of the DICOM standard protocol. Radiology information systems often integrate PACS to facilitate the sharing of images.\textsuperscript{[16]}

**Surgery**

Information technologies in surgery include computer-aided surgery, robotics, and laser surgery. The technologies continue to advance, and practitioners look to use nanotechnology in the future. Computer technology can assist in surgery in several ways. Use of enhanced images and an endoscope, a thin tube connected to a microcamera, enables minimally invasion surgery. Computer-assisted surgical planning makes use of a virtual environment to provide realistic models on which to teach and plan surgical operations.\textsuperscript{[16]}

Several different robotic devises exist to aid in surgery. Robots provide several advantages in the surgical process: robots hold instruments for long periods of time without becoming tired or unsteady, determine proper pressure and tension when manipulating instruments, and can scale down surgical motions. ROBODOC, the first robot used in surgery, performed a hip replacement in 1992. Technologists developed an automated endoscopic system for optimal positioning for the space program, but it now assists in endoscopic surgical procedures. Surgeons use the ZEUS robotic surgical system for minimally invasive microsurgery; ZEUS’s computer-controlled arms scale back the surgeon’s movements and filter out hand tremors. Developers created daVinci for use in endoscopic cardiac bypass surgery, mitral valve repairs, and coronary bypass procedures. Other robots surgeons use are MINERVA for stereotactic neurosurgical procedures and ARTEMIS for minimally invasive surgeries. These and other robots aid in a variety of surgical techniques. The main problem with robots is the large size of the units, leading to current development of portable sensor-driven robots.\textsuperscript{[16]}

Surgeons use laser surgery to cut, vaporize tumors, and seal small blood vessels. LASIK, a laser surgery technique, corrects vision through reshaping the cornea.\textsuperscript{[16]} Use of computer-aided surgery, robots, and lasers help surgeons perform operations in smaller areas with greater precision and increased patient safety.

**Public Health**

Public health informatics is the use of technology to research and inform the practice of public health. In particular, epidemiologists, who use statistical data collection and analysis to study public health, can perform research more efficiently and effectively. One means of study involves the use of computer simulations such as the Models of Infectious Disease Agent Study to study influenza outbreaks. Syndromic surveillance is a modeling approach aimed at the containment of infectious diseases through the use of healthcare data that can indicate probable cases or outbreaks. The National Electronic Disease Surveillance System is part of the public health information network in the United States that uses health data in the prediction of possible epidemics. The Joint United Nations Programme on HIV/AIDS is an epidemiologic software tool researchers use to map and predict the spread of HIV/AIDS.\textsuperscript{[16]}

**DATA STEWARDSHIP**

An important issue healthcare professionals need to address is data stewardship. In the context of healthcare, data stewardship pertains to balancing the rights of patients to have their data protected with improvements in effectiveness of the health system. Data stewardship encompasses all activities related to collection, use, disclosure, management, and security of health information.\textsuperscript{[17]} Essentially a data steward has the role of maintaining the accuracy, security, and availability of data. As diverse entities share health data, several data stewards will be responsible for the data; in fact, one site may require multiple data stewards. For example, the data for one patient may be under the control of a data steward at the primary care office, multiple data stewards at a hospital (admissions office, laboratory, and radiology department), a data steward at the health insurer, and a data steward at the pharmacy. An important area of consideration related to data stewardship is the reuse of health data. Researchers access health data to perform studies and generate information used for improvement of public health.

Researchers have established principles related to data stewardship: accountability, transparency, notice to patients, technical issues, patient consent, permitted use and disclosures, and enforcement and remedies. Accountability entails the application of and adherence to government or healthcare agency regulations. Transparency is the existence of clear, understandable policies and procedures for storage, processing, and delivery of data as well as related business processes and practices. Notice to patients relates to permitted use and disclosures, which involve the use of patient data for studies. The patients must give consent for researchers to use healthcare data for studies (known as secondary use of data) and must receive notice whenever researchers use the data. Technical issues involve the maintenance of
quality and security of data as well as deidentification of data earmarked for secondary use. Administrators need to establish methods to enforce policies and procedures related to the quality, security, and privacy of data and establish remedies regarding problems pertaining to the data quality, security, or privacy.[1,17] Several areas for improvement exist in the data governance area in healthcare. Healthcare professionals need to establish and monitor data ownership and security policies. System developers need to design data architecture and governance models to ensure improved management and sharing of healthcare data within organizations. Data models need to comply with all relevant standards.[4]

**BIG DATA AND HEALTHCARE**

The current phenomenon of big data also has a tremendous positive effect on the healthcare industry. The term big data comes from the fact that the datasets stored and analyzed are huge. The data exist in nontraditional forms such as multimedia and unstructured text data. The nontraditional sources generating the data include environmental sensors and the Internet. Advances in data storage technology and processing enabled the development of a variety of big data technologies.[18]

The collection of healthcare data from sensors, surveys, and other big data-related sources enables the study of health data through the development of data analytics engines. Data analytics allows such activities as the comparison of data between healthcare providers and health insurer networks, determination of factors driving the performance of health insurers, and improvement of healthcare through the use of the best-performing providers.[4]

Google Flu Trends, an example of big data’s use in healthcare, is a query model aimed at predicting and estimating the intensity of influenza epidemics. Google started using the query model based upon Internet search terms to estimate national, regional, and state influenza like illness (ILI) activity. Researchers derived the model by fitting linear regression models to weekly counts of search queries related to ILI activity submitted between 2003 and 2007. The emergence of a pandemic influenza virus in 2009 that researchers did not detect using the system led the researchers to revise the algorithm. The new Google Flu Trends model used retrospective estimates from the revised algorithm. Both the original and the updated Google Flu Trends models demonstrate a high retrospective correlation with national and regional ILI surveillance data at the respective levels. Google Flu Trends also indicated a strong correlation with emergency department influenza cases at the local level.[9,19]

The ability of Google Flu Trends to forecast influenza epidemics is questionable. Researchers have found problems with both the original and the modified models. Researchers hypothesized that the problems could stem from changes in internet search activity and differences found in epidemics between the development and use of the models. Differences in epidemics include seasonality, geographical heterogeneity, and age distribution. Researchers concluded that the Google Flu Trends data should be interpreted with caution until developers further refine the algorithm. However, the use of near-real time electronic health data and refined computational methods for model fitting could have a positive impact on the development of influenza surveillance systems.[9]

Several current big data initiatives in healthcare aim to increase the value of healthcare. Kaiser Permanente, a major healthcare system, has implemented an extensively integrated EHR system called HealthConnect across all of its facilities. Analysis of operation of the HealthConnect system indicates a reduction of office visits by 26.2% and an eightfold increase in scheduled telephone visits.[4] Due to the sharing of data among all of the facilities in Kaiser Permanente, physicians are able to conduct telephone consultations with patients rather than need to schedule office visits for follow-up appointments after tests.

Sanofi, as major pharmaceutical firm, used big data to reverse the rejection by G-BA, a German payor, for coverage of its product Lantus, a form of insulin. Big data research allowed Sanofi to prove that Lantus use resulted in a 17% higher persistence, delaying possible need for expensive conventional therapy. Blue Shield of California is partnering with Nant Health to use big data in advancement of care delivery through improved evidence-based personal health care. AstraZeneca and HealthCore, a subsidiary of WellPoint, are conducting studies to find the most effective and economical treatments for both chronic diseases and common ailments. Employers such as Providence Everett Medical Center conduct programs offering financial rewards or other incentives to employees meeting designated wellness criteria. Providence Everett Medical Center documented a 14% reduction in employee health cost and a 20% decrease in sick leave.[4]

Big data has spurred several healthcare innovations. Asthmopolis developed a GPS-enabled tracking system that monitors when asthmatics use inhalers. Researchers store and analyze the tracking information in conjunction with data related to known asthma catalysts from the Centers for Disease Control. The goal is to aid physicians in developing treatment plans for asthmatics. Ginger.io has developed a smartphone application that integrates data obtained from the app and cellphone sensors with publicly available research by the National Institutes of Health and other such sources of behavioral
health data. The goal of the app is to monitor activity that could indicate illness or anxiety. mHealthCoach uses data to provide education about the patients’ conditions and to aid the patients in following the prescribed treatments. The Healthcare Cost and Utilization Project, sponsored by the Agency for Healthcare Research and Quality, as well as numerous clinical trials are the sources of data for mHealthCoach. Rise Health has developed a dashboard for healthcare providers to improve collection, storage, and exchange of information.[4]

As the use of big data increases in healthcare, developers must address several concerns. Data governance efforts must increase and become more standardized. Developers must design mechanisms for sharing data that maintain patient privacy and security. Industry analysts must develop better overall capabilities in the areas of data analysis, data management, and system management.[4]

CONCLUSION

HITs play a pivotal role in delivering healthcare services and conducting research in pharmacology, epidemiology, and public health. Regulations and standards provide a framework for HIT usage and operation, but, unfortunately, at times contradict each other, hampering efforts to effectively use and share data. HITs are subject to standards pertaining to both healthcare and computing. Initial HIT use involved data collection and storage in the form of EHR. With advances in computing technology, HIT expanded to include PHR, eRx, CPOE, and CDSS. A proposed national infrastructure for health data sharing in the United States, the NwHIN, is still under development. Two different models currently exist for the NwHIN expansion: decentralized through the use of RHIOs, or centralized under government management.

HITs enable the delivery of modern healthcare services. Radiology practitioners use ultrasound, CT scans, MRIs, PET scans, SPECT scans, and DEXA scans regularly. Professionals store and share radiological data using PACS, which are often integrated with EHR systems. Surgeons frequently use computer-aided surgery, robotics, or lasers to either aid or perform operations and procedures.

The dependence upon HIT-generated data leads to the increased vigilance regarding accuracy, privacy, and security. Data governance is a growing area that addresses issues related to data accuracy, privacy, and security. The role of the data steward is a key aspect in data governance and employees with the designation of data stewards have a crucial role in ensuring accuracy, availability, and security of healthcare data.

The term “big data” refers to the collection and use of data from a variety of sources in the decision making and research processes. Healthcare professionals acquire data through the use of a plethora of scanners in the environment or the Internet. Pharmaceutical researchers and medical researchers use big data to create the next generation of drugs, medical devices, and procedures.

The use of HIT and related data will continue to grow as new computing-related technologies develop further. Standards and regulations have an important influence on HIT use, and therefore agencies must examine and refine these codes to ensure compatibility with one another. The dual promises of HIT are the improvement of healthcare and simultaneous decrease in associated costs.

REFERENCES

1. Purcell, B.M. Examining the Relationship Between Electronic Health Record Interoperability and Quality Management in School of Business and Technology Management; Northcentral University, UMI Dissertation Publishing: Ann Arbor, MI, 2013.