Health Information Technology: Has its adoption been worth it?

Salahuddin Kazi

Internal Medicine Grand Rounds
January 29th, 2016

Salahuddin Kazi, M.D.
Professor of Medicine
Division of Rheumatic Diseases
Vice Chair for Education
Program Director Internal Medicine Residency Training

Purpose and overview

The last decade has seen the rapidly accelerating adoption of health information technology in the practice of medicine. Several federal initiatives and regulations have helped accelerate its implementation. A number of unintended consequences have resulted from this process and have had a profound impact on the practice of medicine. While many benefits have resulted from the utilization of health information technology in patient care as well as in business intelligence, the results have been mixed. The medical community is still adapting to the impact of health information technology. Health information technology holds considerable promise (which is yet to be fully utilized) in delivering high-quality safe care with the potential for cost savings, improving population health and the realization of operational efficiency. Despite the mixed results, considerable information has accumulated in our individual data systems. Collective knowledge is hampered by imperfect interoperability of this information. Disease registries and individual data warehouse initiatives have provided considerable insight in population health and hold the promise for the creation of a learning health care system. While the future is uncertain, it is likely that interoperability will be realized and the investment in technology will bear fruit.

Learning objectives

1. Recognize the factors that accelerated the adoption of electronic health records in medical practice
2. Understand the regulations behind the use of health information technology
3. Identify the unintended consequences of health information technology
4. Appreciate the utility of disease registries

Nostalgia is the fond remembrance of events as they never really occurred

I graduated from Dow Medical College (Karachi, Pakistan) in 1987 and afterwards worked as a House Officer in Medicine and Surgery at Civil Hospital Karachi. Charts were in a metal clipboard and most order entry was verbal. Lab work, imaging and ECG's were done manually. I had not seen a computer yet. I began my training as an Internal Medicine Resident at UT Houston Medical School in 1988 using paper charts and scrimmaging through a box for lab results and pressing pedals on the radiology viewing board. Fast forward to1995, I joined the Dallas VA and used DOS based VistA (Veterans Health Information Systems and Technology Architecture) to record notes, order medications and view lab results. With the advent of CPRS GUI (Computerized Patient Record System Graphical User Interface) in 2000, I became a "super user" and recognized the value of shared medical records across the VA system. Leveraging this capability with the Veterans Health Administration, in 2004 I helped start the VA Rheumatoid Arthritis Registry (VARA). Building a new rheumatology practice with Texas Health Resources in 2007, I helped design an Epic rheumatology ambulatory suite of tools and by now had drunk the Kool-Aid and became a staunch supporter of the electronic health record (EHR) transformation of medical care. Still ensconced in the promise of technology, in 2008 I helped launch the American College of Rheumatology's Clinical Registry (RCR) for quality reporting and in 2010 returned to the VA as its

Chief Health Informatics Officer. Working with endusers, I came to the realization that EHR usability was problematic. Despite successes with eConsultation, after visit summaries and Telemedicine, I faced the impossible task of redesigning workflow to permit the effective use of technology. In 2012, I became the 5th program director of the Internal Medicine Residency at UT Southwestern. Still heartened with potential of "a learning health care system" I continued to dabble in health informatics and over the last 2 years have served as the Chair of the Registries and Health informatics Committee which oversees the American College of Rheumatology's new registry, RISE (Rheumatology Informatics System for Effectiveness), which aims to create a national database of rheumatic diseases. Over these the last 20 years, I have witnessed both the effectiveness of and the problems created by the digital age in health care – as software, hardware and humanware have frequently collided. I remain optimistic!

History: Federal Initiatives and Promise

"HIT consists of an enormously diverse set of technologies for transmitting and managing health information for use by consumers, providers, payers, insurers, and all the other groups with an interest in health and health care"- Blumenthal 2007(1)

The history of electronic health records is fascinating in itself and has been well reviewed (2). I want to pick up the story at the point of the creation of the office of the national coor-

dinator (ONC) in 2004, which culminated in the HITECH act in 2009(3). The justification for government intervention in health information technology was based on three premises – that the market had failed to accelerate HIT adoption, that the government needed to define and set standards and that interoperability needed to be promoted. The monetary incentives created were attached to the demonstration of "meaningful use" of the technology. The promise of HIT was to "transform healthcare" by improving individual and population health outcomes, creating transparency and accountability, improving efficiency and ultimately to create a "learning health care system" which could provide new ways of understanding disease and improving healthcare delivery.

The federal health IT strategic plan for 2011-15 (4, 5) recognized the power of health information and bemoaned the underutilization of the technology that could transform health care. The strategic plan set 5 goals:

1. Goal I - Achieve Adoption and Information Exchange through Meaningful Use of Health IT
2. Goal II - Improve Care, Improve Population Health, and Reduce Health Care Costs through the Use of Health IT
3. Goal III - Inspire Confidence and Trust in Health IT
4. Goal IV - Empower Individuals with Health IT to Improve their Health and the Health Care System
5. Goal V - Achieve Rapid Learning and Technological Advancement

The HITECH act set aside $30 billion over 10 years to support the adoption of electronic health records (EHRs) and their "meaningful use". Providers could earn up to $44,000 in Medicare incentives over a consecutive 5-year period. (Medicaid incentives are higher - $63,750). The program began making payments in 2011 and will end in 2016 followed by penalties for not adopting EHRs. In 2008, even though electronic health records had been available for almost 20 years, less than 20% of clinical practices were utilizing electronic health records and the numbers were even smaller for most hospitals. The incentives worked, with EHR adoption soaring to over 75% by the end of 2014. Meaningful use was attached to these payments and while Stage 1 (2011-12), which was based simply on data, capture and basic sharing was achievable, Stage 2 (2014-15) was much harder, with the requirement for advanced clinical processes and clinical decision rules and 17 core measures. Stage 3 is in development and will be rolled out in 2016-17, with a focus on improving outcomes(6). Hospitals had an even greater incentive, between $2,000,000 and $6,370,400 depending on the number of discharges.(7, 8)

The impact of HITECH and meaningful use

While the incentives offered by the federal government were very effective with rapid adoption of technology by both individual providers and hospitals, there were a number of unintended consequences. HITECH worked as a powerful catalyst and while initially Stage 1 was relatively

easy to attain, most healthcare systems are still struggling with achieving Stage 2 mandated meaningful use processes. The principal reason for the difficulty revolves around the lack of cohesion between existing clinical ecologic systems and disruptive impact of the rapid acquisition of technology. Healthcare systems struggled considerably with technology. Many organizations discontinued home-grown healthcare systems and began to adopt commercial electronic health records(9). This was especially true of large networks such as Kaiser Permanente and Geisinger and academic medical centers.

The RAND Corporation published a report in 2005 highlighting the potential of health information technology to realize significant savings while simultaneously increasing safety and improving healthcare outcomes. The analysis suggested that potential efficiency savings for both inpatient and outpatient care could average over $77 billion per year(10). Ten years later, five senators wrote about their concerns regarding the $35 billion federal investment in health information technology(11). The senators were concerned that there was inconclusive evidence that the program had achieved its triple aim of increasing efficiency, reducing costs and improving the quality of care. Furthermore they cited that electronic health records were a leading cause of anxiety for physicians across the country. The estimated $12.5 billion savings were yet to be realized and furthermore it was unlikely that taxpayers would see the savings in the near future. Ironically, Medicare bills rose with the adoption of electronic health records.

A report by the New York Times revealed that hospitals received 1 billion more in Medicare reimbursements in 2010 than they did five years earlier. The principal reason was felt to be the HIT-facilitated ability to use higher billing codes in hospital emergency departments(12).

The barriers to interoperability

Interoperability relies on standard-setting and a common language. Interoperability is relatively easy when dealing with currencies but substantially more complicated in healthcare. While interoperability was one of the goals of the federal health IT strategic plan, sufficient dollars were not allocated to promote interoperability.

In 1999, Sen. Ron Paul of Texas introduced legislation which squashed the initiative to create a unique national health identifier. HIPAA had recognized that a unique identifier for individuals was an essential component of administrative simplification. Instead, each healthcare system creates a unique identifier for the same individual creating multiple references to a single patient across the healthcare system. Having multiple identifiers for the same individual within and across organizations prevents or inhibits timely access to integrated information. The controversy has stemmed from privacy concerns. The interoperability success of the VA healthcare system is principally based on utilizing the Social Security number as the unique health identifier. The lack of a unique health identifier in health information technology is a continuing barrier to interoperability.

EHR vendors themselves had very few incentives to promote interoperability. For many hospitals and health systems, there was a shift to one vendor – Epic. This vendor has dominated most large and medium hospital markets. This domination has stifled efforts toward interoperability. Most of the interoperability occurs within the healthcare system and its existing legacy systems. While epic has championed "care everywhere" there continue to be limitations in the true exchange of information to prevent duplicate services with minimal sharing occurring with other electronic health care records. Epic installations are highly configurable and each Epic installation is considerably unique and tailored to a particular healthcare system. Considerable costs are expended in installations of Epic. Installation and routine maintenance costs have diverted funds and efforts to promote true interoperability(13). As defined by Wikipedia, "vendor lock" also known as the "proprietary lock" refers to a process by which a customer is dependent on a vendor for products and services and is unable to use another vendor without substantial switching costs. Writing in a recent issue of Mother Jones, Patrick Caldwell assailed Epic for failing to promote seamless interoperability despite being the EHR giant with the lion's share of the EHR sector(14). In a 2014 RAND Corporation's report, Epic's limited interoperability was cited to be a major concern(15).

In April 2015, Dr. Karen DeSalvo, the National Coordinator for Health Information Technology, submitted a report to Congress regarding health information blocking(16). She defined information blocking as occurring when persons or entities knowingly and unreasonably interfere with the exchange or use of electronic health information. She noted that most complaints of information blocking were directed at health IT developers. The majority of these complaints alleged that developers charged fees that made it cost prohibitive for most customers to send, receive or export electronic health information stored in EHR's or to establish interfaces that enable such information to be exchanged with other providers, persons or entities.

The direct impact of electronic health records on clinicians

Dr. Robert Wachter, Chair of the Department of Medicine at UCSF recently published "The Digital Doctor", which reviews healthcare's path toward computerization and catalogs the dehumanization of medicine by the entry of the computer in the examination room. He details numerous unanticipated consequences as well as the challenges that the healthcare communities are facing. He has eloquently narrated the ensuing transformation of the clinical ecosystem in the age of information technology(17). The adoption of health information technology involved considerable technical change. Wachter goes on to explain that clinicians have been oblivious to the need for adaptive change when faced with the adoption of health information technology. This especially applies to the need to change existing culture and workflows to incorporate technology.

6

Alert fatigue is a growing concern not just in the electronic health record but in every hospital healthcare system. Most electronic health records have point of care clinical alerts ostensibly to avoid medical errors such as drug-drug interactions or to promote best practices. A study by Nanji in 2014 examining the overriding of medication related clinical decision support alerts in outpatients demonstrated that the alerts fired at a rate of 7.97% in over 2 million medication orders. 52.6% of these alerts were overridden (18). Murphy studied the number of inbox alert information transmitted to 47 primary care practitioners in a VA facility. The primary care physicians received nearly 60 alerts each day containing new information. Practitioners spent an average of 49 minutes per day processing their alerts (19). Because such alerts are asynchronous by their very nature, these do not consistently lend themselves to effective clinical care and caused frequent disruptions in clinician workflow.

Clinicians have increasingly utilized templates to create efficiency in writing clinical notes. While the electronic health records created new tools and more efficient ways to document patient care encounters, a number of new problems have been created including authorship attribution, data integrity as well as regulatory concerns of accuracy and veracity of billing services. Copying and pasting prior notes, and cloning of notes has been the principal cause of these problems. Templated notes have also lost meaning converting potentially complex mental models to simpler EHR language(20).

The electronic health record has also promoted the loss of clinician-patient interaction. In a 2008 perspective article, Abraham Verghese coined the term "iPatient" lamenting the emergence of the "chart-as-surrogate-for-the-patient" approach" present in present-day medical care(21). Furthermore, there is evidence that electronic health records have negatively impacted clinical reasoning by fragmenting data interconnections. The EHR has accordingly created limitations for narrative information. These constraints hinder a shared interprofessional understanding of the patient story (22).

Health information technology adoption has also been associated with loss of productivity. This loss of productivity is especially prominent in the first several months after "go live" with recovery taking up to 12 months(23). Tracking 30 ambulatory practices for two years after EHR implementation, Howley et al., showed that practice productivity fell each quarter when the measure was the number of patients seen. This was offset by increased billing and increased frequency of visits most often related to ancillary services(24). Residency training has also been affected by implementation of health information technology. In one study for residents in a general internal medicine clinic, afterhours electronic health record use was approximately 3 hours/week. 190 duty hour violations would been generated if this usage was included in the residents' reported duty hours(25).

Understanding clinician dissatisfaction

A number of surveys indicate high levels of physician dissatisfaction with health information technology. The Wisconsin Medical Society surveyed its membership in 2014 which revealed high levels of dissatisfaction with their careers(26). Electronic health records were a large driver of the work environment and the ensuing workflow issues led to high rates of dissatisfaction. Eighty-two percent of respondents reported some burnout symptoms. Responding to such reports of dissatisfaction and burnout, Bodenheimer and Sinsky have suggested that the Institute of Medicine's Triple Aim (enhancing patient experience, improving population health, and reducing costs) be expanded to the Quadruple Aim, which would add the goal of improving the worklife of healthcare providers including clinicians and staff(27).

Ross Koppel, a sociologist from the University of Pennsylvania, has written extensively about the interactions between technology and the sociology of healthcare teams(28). Discussing HIT's impact on clinician mental models, he examined 45 scenarios of misalignment between patients' physical realities, clinicians' mental models and EHR's. He identified five general types of misrepresentations. A type I error occurs when the concept, as defined within the electronic health record, is too coarse and potentially represents two different mental models in the same way. For example many variants of lupus nephritis exist. The electronic health record could combine these distinct entities into one concept "lupus nephritis" - which would lose the granularity that had been crafted in the clinician mental model. Occasionally, the electronic health record specifies a degree of clarity that is significantly more specific than the intended mental model. The patient with unspecified inflammatory arthritis may be incorrectly recorded as rheumatoid arthritis. This is a type II error. Given that electronic health records do not interface with all sources of information, missing information is not at all unusual resulting in incomplete transfer of the mental model to the electronic health record. Missing echocardiographic data may not fully corroborate the degree of systolic heart failure. Given that the EHR has become the medium of communication, the transfer of mental models from one clinician to another, as mediated by the EHR, may result in modifying real-world concepts (type IV error). A particularly pervasive error is the result of reviewing one's own mental models at a later time. Because the EHR may not have captured the original mental model as intended, upon reflection a different mental model becomes manifest (type V error - the looking glass).

Koppel also developed the concept of interactive sociotechnical analysis (ISTA). He proposed a framework and typology specifying important relationships between health information technology, clinicians and organizations(29). The framework brought attention to four key features and stressed the importance of examining actual uses of health information technology rather than uses that were intended by designers and managers.

The framework stressed the importance of the technical and physical settings in the workplace and drew attention to users' renegotiation and reinterpretation of the features of the technology. Additionally, interactions and interdependence among social and technical systems were closely linked to recursive relations within the technical subcomponents.

Sociotechnical interactions

Health information technology has profoundly changed the healthcare social system. While the unintended consequences of HIT often focus on the flaws of technology, it is much more likely that sociotechnical interactions play a greater role. The narrow, mechanistic approach of HIT design and implementation overlooks the effects of new information systems on employees and their organizations and fails to grasp the dynamic and interconnected nature of organizations as clinical ecosystems. Prior to the introduction of computerized physician order entry (CPOE), nurses often transcribed verbal orders from physicians typically initiated by nurses who were alert to changes in the patients' conditions. Clinicians subsequently signed these orders retrospectively preventing delays in patient care. CPOE has now constrained a linear workflow, creating several hazards. These include, delays in execution of orders, divergent orders (pharmacist modification) and frequent nurse interruption of physician workflow to request initiation of orders which previously would have been initiated by the nurse.

As hospitals and ambulatory practices deploy health information technology, it has been consistently observed that clinicians now spend more time on documentation and justification of their decisions and there are important changes to communication patterns and practices. There has been an overall decline in vital interaction among health care providers. These informal interactions have been lost along with the redundancy that helped catch errors. We have all witnessed the impact of technology on resident and student teaching and learning. The combination of duty hour restrictions and technology have reduced the frequency of bedside rounding on teaching services.

New types of errors are introduced when clinicians bypass some of the checks and balances built within CPOE by ordering a medication in the miscellaneous orders section. Alert fatigue is highly prevalent as discussed previously and cognitive overload of writing notes in the compulsion to review and document "everything" has led to "copy and paste" and wholesale cloning of notes. This is caused concerns with attribution of authorship and veracity of information. Workflow constraints are particularly notable when admitting patients especially during transfers.

As a system fully ensconced in health information technology we risk the havoc caused during "downtime" or unexpected system failures. We risk the illusion of communication when we believe that entering an order will ensure that the recipient sees and acts upon it. More importantly, narrow role-based authorizations have redis-

tributed work contrary to the social structure of the organization that existed prior to the implementation of technology. Physicians are remarkably independent individuals and have generally recoiled at the ability of organizations to monitor them in a microscopic and precise way. This has resulted in an inversion of power between hospital administration and clinicians.

Healthcare organizations themselves are subject to never-ending demands. The costs of implementing and maintaining technology are in the hundreds of millions of dollars. Upgrades can lead to unexpected incompatibility and system downtime. Healthcare organizations may have divested in file room clerks but have had to hire expensive on-site technological help.

Realizing gains from our investment in technology

There is no doubt that the implementation of healthcare information technology has resulted in the accumulation of vast amounts of digitized data which facilitates analysis in a way that was inconceivable in the paper records age. The use of the term "Big Data" has become prevalent in healthcare as well. A search for this term resulted in the 6697 hits in the National Library of Medicine database. Accordingly there has been considerable interest in big data analytics in healthcare(30). By definition big data refers to data sets that are so large and complex that they are difficult (if not impossible) to manage with traditional software and/or hardware. Healthcare data have the potential

characteristics of big data - volume, velocity and variety. The potential to derive value from this information is limited by the veracity of the information. While structured data are the easiest to retrieve and analyze, capturing physician mental models and the complexities of healthcare delivery (often distorted by the electronic health record or captured in narrative text) are difficult to analyze. Natural language processing and machine based learning are important advances in harnessing data in electronic health records. A detailed discussion of the challenges and opportunities of big data in healthcare are beyond the scope of this grand rounds. I would like to focus on the importance of disease registries and the emerging ability to analyze data within a single healthcare system.

The value of registries in healthcare

The United States has approximately 5,000 practicing rheumatologists who provide care to approximately 10,000,000 patients with rheumatic diseases. Relatively uncommon diseases characterize rheumatology and the harnessing of this collective knowledge is an important endeavor to understand the delivery of healthcare and permit new discoveries. Valuable information is trapped within the individual EHR's of practitioners. This is the real world information that is distinctly different from practice guidelines derived from patients enrolled in clinical trials. Only 5% of patients in clinical practice would qualify for a clinical trial in rheumatology(31). Furthermore the real promise of health information

technology is to create "a rapid-learning healthcare system" which would permit the study of population health, help improve outcomes and reduce costs thereby increasing value(32).

Sweden is the poster child of the value of chronic disease registries to(33). As a nation, it has been an international pacesetter in the establishment of chronic disease registries. Important-ly, Sweden uses a unique national pa-tient identifier. This is critical to col-lating information and prevents dupli-cation of data. There are 104 govern-ment-sponsored registries typically administered by specialty medical so-cieties. It is estimated that $7 billion of savings were realized in 10 years. More importantly patient outcomes have been demonstrated to consist-ently improve. The Swedish register of quality (SRQ) was one of the first chronic disease registries in Sweden for rheumatology. It has enrolled all 60 rheumatic disease clinics in the na-tion and has captured information for almost 60,000 patients. Much of this information is longitudinal and has provided remarkable improvements in the care of rheumatic conditions. The Swedish registries have empha-sized the importance of coproduction models of care and have routinely in-cluded patient derived information.

There are several disease registries in the United States but these typically are data poor claims databases or in-volve web-based entry or paper-based case report forms. Uploading raw elec-tronic health record data provides much more information and permits broad analysis. Automated EHR data capture facilitates a much more con-sistent view of the real world. Because the system is always on, the infor-mation is often in real-time. Because the information is raw, it requires considerable effort to clean and col-late this information at the back end.

In 2014, the American College of Rheumatology launched a national disease registry (RISE - rheumatology informatics system for effectiveness) based on automated upload from con-nected electronic health records. Within a year, data from over 200,000 patients from 50 connected clinical practices (302 clinicians) were up-loaded to the RISE registry. An analy-sis of these data revealed that it was broadly representative of real-world patients and afforded data for over 50,000 rheumatoid arthritis patients as well as details regarding their med-ications and other parameters of in-terest. Several relatively uncommon conditions were also collected in large enough numbers to permit the gener-ation of new knowledge. The registry is currently principally used to meas-ure and report quality and provide useful clinical dashboards for individ-ual practices to improve patient care. The registry is owned by the American College of Rheumatology and devel-oped in association with FigMD also hosts the American College of Cardiol-ogy's Pinnacle registry. It has already collected more patients than the Swe-dish rheumatology registry (SQR). Be-cause the data are directly uploaded from electronic health records, exten-sive data mapping is required along with development of electronic quality measures to facilitate quality report-ing. The RISE registry is a qualified clinical data registry (QCDR). Partici-pation in the registry has shown

strong growth over the last 18 months. The registry provides a very valuable database for research and discovery. Efforts are underway to partner with data analytic centers to facilitate data analysis and research activities.

The Parkland Epic system has invested in significant data warehouse initiatives including the creation of a diabetes disease registry. Tools that are available to users includes the visually-based "SlicerDicer". This tool permits rudimentary analysis of structured information within the electronic health record. I believe that its power is based on longitudinal data on 3 million patients extending over 10 years and the diversity of the patient population. The Parkland patient population includes significant numbers of minority patients who have been typically understudied in other databases. The veracity and value of this tool are yet to be determined. Clearly this tool is in its infancy but its potential for managing healthcare is an enormous.

New regulations and incentives

The Center for Medicare and Medicaid services continues to roll out initiatives to help achieve high value care. In April 2015, Congress passed the Medicare Access and CHIP Reauthorization Act of 2015 (MACRA). This act permanently repealed the flawed Sustainable Growth Rate (SGR) formula for determining Medicare payments. It establishes a new framework for rewarding clinicians (value over volume) and streamlines other existing quality reporting programs into a new system. Individual payments for meaningful use and physicians quality reporting as well as the value-based modifier will be combined under one metric. MACRA proposes using Merit-Based Incentive Payment System (MIPS) along with eligible Alternative Payment Models (APMs). MIPS will adjust payments beginning in 2019 (8% at risk) which will grow up to 18% payment adjustments in 2022. This legislation provides a powerful incentive to participate in accountable care organizations. It will also pave the way to continue the movement from a fee-for-service system to payment for outcomes. It is expected that this legislation will accelerate interoperability which has stalled. It is my hope that it will catalyze the development of disease registries to measure value and improve health care delivery. I expect that clinical dashboards provided by disease registries will provide much-needed feedback and tools for the measurement of value.

Earlier this month, the acting administrator for CMS, Andy Slavitt, announced that the meaningful use program will be replaced with a better one. He stressed that outcomes will be more important than the use of technology. He reiterated that technology must be user centered and support physicians. He indicated that CMS would require open application programming interfaces to promote interoperability.

The path forward

We are still in the age that is witnessing the unfolding of the effects of rapid growth in health information technol-

ogy and have suffered its unintended consequences. In the age of the iPhone, we have come to expect intuitive interfaces that the electronic health records have struggled to provide. While user centered design is the norm in the aviation industry that has not been the norm in the health information technology industry. A greater understanding of social informatics will help foster user centered redesign of electronic health records and reduce the number of alerts to those that are especially relevant and meaningful. Developing better mental models by utilizing collaborative tools such as SNOMED-CT and utilizing disease registries will permit us to face the challenges of accountable care. Barriers to true interoperability will eventually fade and the addition of natural language processing and machine-based learning will contribute to the development of a rapid learning healthcare system. It is entirely possible that the entire patient record will be based in the cloud and will profit from a single source of truth. We may develop the necessary computing capabilities to harness the Big Data that are accumulating in the electronic health records across the nation. As a nation we spend much more per capita than any other country on healthcare. We have also suffered considerably with the adoption of health information technology. Healthcare providers have witnessed a disruption of the clinical ecosystem with increasing rates of burnout. It is imperative that we redesign our healthcare system to achieve the Quadruple Aim which includes the care of the healthcare provider.

References

1. Blumenthal D, Glaser JP. Information technology comes to medicine. N Engl J Med. 2007;356(24):2527-34.
2. Haux R. Health information systems - past, present, future. Int J Med Inform. 2006;75(3-4):268-81.
3. Blumenthal D. Launching HITECH. N Engl J Med. 2010;362(5):382-5.
4. Office of the National Coordinator for Health Information Technology DoH, Human S. Health information technology: standards, implementation specifications, and certification criteria for electronic health record technology, 2014 edition; revisions to the permanent certification program for health information technology. Final rule. Fed Regist. 2012;77(171):54163-292.
5. Office of the National Coordinator for Health Information Technology DoH 2011;Pageshttps://www.healthit.gov/sites/default/files/utility/final-federal-health-it-strategic-plan-0911.pdf2016.
6. Medicare and Medicaid Programs; Electronic Health Record Incentive Program-Stage 3. 2015.
7. Blumenthal D. Implementation of the federal health information technology initiative. N Engl J Med. 2011;365(25):2426-31.
8. Blumenthal D, Tavenner M. The "meaningful use" regulation for

electronic health records. N Engl J Med. 2010;363(6):501-4.

9. Classen DC, Bates DW. Finding the meaning in meaningful use. N Engl J Med. 2011;365(9):855-8.

10. Hillestad R, Bigelow J, Bower A, Girosi F, Meili R, Scoville R, et al. Can electronic medical record systems transform health care? Potential health benefits, savings, and costs. Health Aff (Millwood). 2005;24(5):1103-17.

11. 2015;Pages. Accessed at Health Affairs at http://healthaffairs.org/blog/2015/03/04/where-is-hitechs-35-billion-dollar-investment-going/2016.

12. Medicare Bills Rise as Records Turn Electronic. The New York Times; 2012.

13. Koppel R, Lehmann CU. Implications of an emerging EHR monoculture for hospitals and healthcare systems. J Am Med Inform Assoc. 2015;22(2):465-71.

14. Caldwell P. Epic Fail. Mother Jones. 2015.

15. Corporation R. Redirecting Innovation in U.S. Health Care: Options to Decrease Spending and Increase Value. 2014.

16. DeSalvo K. Report on Health Information Blocking. The Office of the National Coordinator for Health Information Technology; 2015.

17. Wachter R. The Digital Doctor. San Francisco: McGraw-Hill education; 2015.

18. Nanji KC, Slight SP, Seger DL, Cho I, Fiskio JM, Redden LM, et al. Overrides of medication-related clinical decision support alerts in outpatients. J Am Med Inform Assoc. 2014;21(3):487-91.

19. Murphy DR, Reis B, Sittig DF, Singh H. Notifications received by primary care practitioners in electronic health records: a taxonomy and time analysis. Am J Med. 2012;125(2):209 e1-7.

20. Sheehy AM, Weissburg DJ, Dean SM. The role of copy-and-paste in the hospital electronic health record. JAMA Intern Med. 2014;174(8):1217-8.

21. Verghese A. Culture shock--patient as icon, icon as patient. N Engl J Med. 2008;359(26):2748-51.

22. Varpio L, Rashotte J, Day K, King J, Kuziemsky C, Parush A. The EHR and building the patient's story: A qualitative investigation of how EHR use obstructs a vital clinical activity. Int J Med Inform. 2015;84(12):1019-28.

23. Fleming NS, Becker ER, Culler SD, Cheng D, McCorkle R, da Graca B, et al. The impact of electronic health records on workflow and financial measures in primary care practices. Health Serv Res. 2014;49(1 Pt 2):405-20.

24. Howley MJ, Chou EY, Hansen N, Dalrymple PW. The long-term financial impact of electronic health record implementation. J Am Med Inform Assoc. 2015;22(2):443-52.

25. Gilleland M, Komis K, Chawla S, Fernandez S, Fishman M, Adams M. Resident duty hours in the outpatient electronic

health record era: inaccuracies and implications. J Grad Med Educ. 2014;6(1):151-4.

26. Coleman M, Dexter D, Nankivil N. Factors Affecting Physician Satisfaction and Wisconsin Medical Society Strategies to Drive Change. WMJ. 2015;114(4):135-42.

27. Bodenheimer T, Sinsky C. From triple to quadruple aim: care of the patient requires care of the provider. Ann Fam Med. 2014;12(6):573-6.

28. Smith SW, Koppel R. Healthcare information technology's relativity problems: a typology of how patients' physical reality, clinicians' mental models, and healthcare information technology differ. J Am Med Inform Assoc. 2014;21(1):117-31.

29. Harrison MI, Koppel R, Bar-Lev S. Unintended consequences of information technologies in health care--an interactive sociotechnical analysis. J Am Med Inform Assoc. 2007;14(5):542-9.

30. Raghupathi W, Raghupathi V. Big data analytics in healthcare: promise and potential. Health Inf Sci Syst. 2014;2:3.

31. Sokka T, Pincus T. Eligibility of patients in routine care for major clinical trials of anti-tumor necrosis factor alpha agents in rheumatoid arthritis. Arthritis Rheum. 2003;48(2):313-8.

32. Etheredge LM. A rapid-learning health system. Health Aff (Millwood). 2007;26(2):w107-18.

33. Larsson S, Lawyer P, Garellick G, Lindahl B, Lundstrom M. Use of 13 disease registries in 5 countries demonstrates the potential to use outcome data to improve health care's value. Health Aff (Millwood). 2012;31(1):220-7.