**Reducing Clinician Burden by Improving Electronic**

**Health Record Usability and Support for Clinical Workflow**

**HL7 Reducing Clinician Burden Project**

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**Abstract**

Despite support from over $35 billion in public funds, most of electronic health records’ (EHRs’) promises to improve healthcare quality, safety, and cost efficiency remain unfulfilled. A large and growing body of data suggests that poor usability and poor integration with clinical workflow are the most important factors preventing EHRs from achieving their design goals. In addition, the burdens imposed on clinicians by these systems are strongly associated with an epidemic of clinician burnout and patient dissatisfaction. As part of the Health Level 7 International (HL7) Reducing Clinician Project, we performed an environmental scan and literature review to enumerate and define EHR-related clinician burdens associated with clinical workflow and documentation. Based on their history and underlying causes, burdens fall into two categories: those related to interactions between clinicians and the regulatory and organizational environment, but implemented via the EHR (extrinsic), and those caused by interactions between clinicians and the EHR technology itself (intrinsic). Here we evaluate the details of several major types of clinician burden and briefly propose potential solutions that are more than just incremental extensions of current methods and EHR products. We conclude it will take disruptive innovation and entirely new frameworks and perspectives for EHRs to help achieve our goals. We highlight ideas from the literature that can form the basis for truly novel EHR designs that better support clinician workflows and thereby enable better patient care.

**Introduction**

**Historical Perspective**

When the Health Information Technology for Economic and Clinical Health (HITECH) provisions of the American Recovery and Reinvestment Act (ARRA) of 2009 were passed, the vision was widespread adoption of electronic health records (EHRs) to support national objectives of improving healthcare quality and safety, improving the patient experience, and improving the cost efficiency of the American healthcare system.[1] A decade later, EHRs are implemented in more than 95% of hospitals and nearly 90% of physician offices, while studies have shown:

* No significant change in hospital length of stay or inpatient mortality[2,3]
* No significant change in 30-day readmission rates or patient safety incidents[2,3]
* No improvement in life expectancy, infant mortality, or other population metrics[4,5]
* Continued rapid rise in annual healthcare expenditures from $2 trillion in 2009 to over $3.5 trillion in 2017 (nearly 18% of GDP)[6]
* Decreased efficiency in healthcare delivery (EHRs add 1-2 hours to the average physician workday)[7,8]
* Disruption of physician work-life balance associated with an epidemic of provider burnout[9-11]
* Modest improvement in care process metrics and guideline adherence only weakly correlated with EHR use[12-14]

What happened? Why did we encounter so many unanticipated consequences? Why do most of EHRs’ promises remain unfulfilled? What have we learned from the first decade of large scale EHR implementation to solve the problems and improve EHRs?

**Poor Usability**

A large and growing body of data suggests that poor usability and poor support for and integration into clinical workflow are among the most important factors preventing EHRs from achieving their intended design goals.[15,16] Current generation EHRs evolved rapidly from systems designed primarily for billing and administrative purposes, and have yet to be optimized to support the actual work done in patient care delivery. Suboptimal human factors engineering in EHR design creates a challenging user experience leading to decreased clinical productivity, increased error rates, increased user fatigue among providers, and decreased user satisfaction.[15] As noted by the Institute of Medicine:[17]

*Designed and applied inappropriately, health IT can add an additional layer of complexity to the already complex delivery of health care, which can lead to unintended adverse consequences, for example dosing errors, failure to detect fatal illnesses, and delayed treatment due to poor human–computer interactions or loss of data.*

and

*Although definitive evidence is hard to produce, the committee believes poor user-interface design, poor workflow, and complex data interfaces are threats to patient safety.*

Healthcare quality and safety are emergent properties which arise from a sociotechnical healthcare system, typically represented by a five-domain model including interactions among people, processes, technology, organizations, and external environment.[17,18] Under the pressure of large regulatory incentives and penalties, current generation health IT solutions (including EHRs) were hastily implemented based on the systems and models available at the time they were designed. Development has been focused on meeting the requirements of EHR certification rather than clinical functionality or usability. These systems were not optimized to accomplish what clinicians need for bedside care nor do the EHRs adequately incorporate the large existing body of knowledge about human factors and human safety engineering. As a result, current EHRs and health IT systems fail to achieve the right balance between clinicians and technology and pave a path to widespread clinician burnout, heightened patient dissatisfaction, and increased safety risks.[9,10,17,19]

In addition to problems at the intersection of people and technology, EHRs have also exacerbated healthcare delivery problems at the intersection between people and the external environment. Reimbursement regulations significantly increase the time and effort necessary for clinicians to document care in the medical record.[20] Large scale poorly coordinated administrative and regulatory reporting programs intended to measure quality improvement and the use of healthcare information technology (health IT) have diverted attention and effort from direct patient care to reimbursement and administrative activities with minimal clinical value.[21] And, there is little evidence such reporting programs have improved the quality of care in any meaningful way (see above).

**The HL7 Reducing Clinician Burden Project**

Viewed from another perspective, widescale implementation of EHRs over the last decade has imposed additional stress, additional physical and cognitive workload, and additional time requirements (“burden”) on healthcare professionals (“clinicians”). whose practice is based on direct observation and treatment of patients. The Reducing Clinician Burden (RCB) Project is an activity of Health Level Seven (HL7) International, a not-for-profit American National Standards Institute (ANSI)-accredited standards development organization, aimed at enumerating and defining specific EHR and health IT burdens, understanding the history and underlying cause of those burdens, and proposing novel, innovative solutions for alleviating the burdens.[22] The project also aims to document and share current success stories and best practices in alleviating clinician burden. Using extensive literature review,[22] the project has documented EHR-related burdens in multiple domains (see Table 1).

Table 1. Types of clinician burden related to the EHR

|  |  |
| --- | --- |
| Clinical workflow and documentation | User training and proficiency |
| Human factors and usability | Developer transparency and responsibility |
| Patient safety | Interoperability |
| Clinician-patient interaction | Legal aspects and risks |
| Clinical decision support | Effect of health IT on nursing practice |
| Administrative tasks | Support for public and population health |
| Care coordination and team management | Data integrity and reliability |

This report presents a literature analysis by the RCB Project clinical workflow and documentation focus team to define clinician burdens in these two domains, understand the underlying causes, and propose new, effective solutions that are more than incremental extensions of current methods and EHR products. We chose to emphasize these areas because they are the most important to front line practicing clinicians and because they encompass many of the other categories (e.g., human factors, patient safety, clinician-patient interaction, clinical decision support, and non-clinical administrative tasks). As discussed above, we found two major categories of workflow burdens, those related to the interactions between clinicians and the regulatory and organizational environment, but implemented via the EHR (extrinsic), and burdens caused by interaction with the EHR technology itself (intrinsic). We conclude that disruptive innovation and entirely new frameworks and perspectives will be needed for EHRs to mitigate, reduce, or alleviate the burdens and enable clinicians to deliver safer, higher quality, more cost-effective healthcare.

**Clinical Workflow**

The term “clinical workflow” encompasses all clinician physical and mental activities, technologies, tools, environments, teams, and organizations involved in patient care.[23] As such, clinical workflows are sequences of physical and cognitive actions, occurring over time and through space, which:

* Are performed by clinicians
* Consume, transform, and/or produce information
* Are used to assess, maintain, or change the health of a patient.[24]

Such activities may include but are not limited to 1) direct interaction with patients, 2) finding, organizing, and analyzing data and information from the medical record, 3) researching information from the medical and scientific literature, 4) making diagnoses and clinical decisions, 5) writing orders and making referrals, 6) care coordination and collaboration, 7) population management, 8) clinical documentation, and 9) information sharing with patients and members of the clinical team.

**Burden Definitions and History**

**Extrinsic Burdens**

The large-scale adoption of EHRs has served to reveal and highlight a number of longstanding problems with the healthcare system. Operationalizing certain common processes within the EHR has created unexpected and unintended impediments to workflow.[25] An effective digital transformation cannot be achieved without addressing these issues, which we enumerate and define here.

*Clinical documentation requirements*

In 1995, the Health Care Financing Administration (HCFA; predecessor of the Department of Health and Human Services (DHHS) Center for Medicare and Medicaid Services (CMS))developed Evaluation and Management (E&M) guidelines to prevent clinicians from billing at levels not justified by the documentation of their clinical work. The E&M codes, updated in 1997, defined encounter billing levels by “objective, quantifiable, auditable” standards based on information recorded in the medical record. Failure to conform with the E&M guidelines is punishable by fines, imprisonment, and/or decertification from the Medicare Program for billing fraud, so physicians approach E&M-based documentation very seriously.[26] Similar standards were rapidly adopted by the great majority of private payers.

Unfortunately, the 1997 CMS E&M guidelines were not based on a scientific examination of what documentation should be included in a clinical note. The guidelines require multiple documentation components with little relevance to the encounter being recorded and little connection to the effort, complexity of medical decision making, or quality of care involved. Even at the time of release, the American Medical Association (AMA) and 38 medical professional societies found the guidelines burdensome, confusing, and flawed, and multiple calls for reform over more than 20 years have yet to be heeded.[26] To be sufficiently complete and granular to meet E&M coding requirements, physicians commonly create templates and employ copy/paste functionalities which often produce verbose, disorganized, repetitive notes that successfully meet CMS coding and audit requirements but often make it extremely difficult for other clinicians to find, organize, and understand the clinical information most pertinent for patient care.[20,27]

*Non-clinical documentation requirements*

The rapid adoption of EHRs has also introduced an additional layer of regulatory burdens related to reimbursement justification, quality improvement, and health IT utilization measurement. For example, a recent AMA study with 1000 respondents found that 92% said prior authorization (PA) caused delays in patient care and 61% said PA had a negative effect on clinical outcomes. Physicians reported they spent an average of 14.6 hours per week on activities related to PA, time which could be spent more productively on direct patient care. Similarly, contesting insurance coverage denials that are not medically appropriate consumes significant clinician time and effort in activities which are not clinically useful.[28]

Although such programs are well intentioned, collecting data required for Meaningful Use, Merit based Incentive Payment System (MIPS), as established by the Medicare Access and CHIP Reauthorization Act of 2015 (MACRA), etc. further intrudes on the limited time physicians have with each patient. In addition, these reimbursement programs all focus on process measures with little evidence that such measures have meaningfully improved large-scale health outcomes.[29] The mandated use of physician attested ICD-10 codes requires time-intensive selection from large, confusing arrays of choices. ICD-10 codes often require information which may not be available in the early stages of care, creating scenarios where precise and incorrect information is recorded rather than a more general assessment better aligned with the data available at the time.

*Physician burnout*

Extensive clinical and nonclinical documentation regulations, enabled and implemented through the EHR, increase workflow steps and increase demands on physicians’ time, visual recognition processes, working memory, and concentration (together termed cognitive load). This increased cognitive load often results in in delayed decision making, an increased risk of errors, and significant disruption of the physician-patient relationship. The most highly trained members of the care team, the front line physicians and nurses, are too often utilized as data entry clerks, responsible for diagnoses, treatment orders, care coordination, and visit notes, but also for vast amounts of lower level data with much less clinical value.[30]

By definition, clinician burnout is a syndrome emerging as a prolonged response to chronic interpersonal stressors on the job and characterized by feelings of emotional exhaustion, cynicism and detachment from work, and a sense of low personal accomplishment.[31] About 50% of US physicians report at least one symptom of burnout (twice the rate of the general population), and 70% of US physicians report symptoms of health IT-related stress.[10] The time consumed by the multiple inefficiencies related to regulation-induced documentation burdens disrupts work-life balance and is a major contributor to the current epidemic of physician burnout seen in the US.[9-11,30] A number of studies have also shown that the prevalence of physician burnout correlates directly with usage of and frustration with EHRs.[9,10,32]

*Gaps in regulation of EHR software development*

Incorporating user-centered design (UCD) processes during development is “required” for EHR certification. Yet EHR software developers vary widely in understanding and implementation of UCD processes.[33,34] Currently, no standard measurements of usability are required, and regulations permit non-transparent developer self-attestation making it impossible for purchasers to directly compare products.[35] Many clinicians use different EHRs in different contexts. Dealing with different interface designs, icon sets, and workflow steps can create additional usability and safety challenges. Lack of interface level design specifications in the EHR certification process bypasses a potentially useful method for mitigating these problems.[35,36]

Usability and safety issues can arise at many points in the health IT software lifecycle including design and development, implementation, customization by organizations, and personalization by users. Uncovering the root cause(s) of issues and solving the problems requires good faith collaboration between developers, organizations, and users. Many health IT contracts between developers and organizations contain “hold harmless clauses” that protect developers from liabilities and intellectual property protections (“gag clauses”) that prevent sharing of screenshots and other material which would help with problem solving. Such contract elements prevent developer accountability and impede root cause analysis of safety problems.[35]

*Organizational Stressors and Moral Injury*

The idea that healthcare should be patient-centered is one of the foundational tenets of the healthcare system. Similarly, from the earliest steps on the pathway to becoming healthcare providers, individual clinicians become deeply committed to a foundational moral principle: The needs of the patient come first. Recently, the daily experience of clinical practice has been increasingly affected by insufficient resources, demands for system performance improvement, production pressures, and changes in reimbursement structures.[11] Under hazard to personal financial viability, clinicians now face strong pressure to consider the needs of the EHR, the payers (public and private), associated healthcare organizations, and government regulators as relevant and potentially equivalent with the needs of their patients.[37]

Exacerbated by inefficiencies related to the EHR, the demands on clinicians have escalated exponentially without any corresponding increase in time with patients or resources. To meet the demands and satisfy intrinsic requirements and standards of providing the best possible care, clinicians devote lunch hours, evenings, and weekends to completing documentation. If most doctors and nurses just signed out and stopped work at the end of their shifts, the healthcare system would collapse.[38] Despite best efforts, clinicians often cannot escape the double bind of knowing what the patient needs and awareness of being unable to meet the need due to circumstances beyond their control, a phenomenon termed “moral injury.”[37]

**Intrinsic Burdens**

Current EHR design and implementation paradigms were based on the scientific principles and historical precedents available when the products were developed. However, these systems unduly rely on the principle that there is one ideal workflow to carry out and document a given clinical process that is valid and optimal in all contexts. This encourages the suppression of clinical practice variability. Yet variability in clinical practice is nearly inevitable (see below). In failing to adequately account for cognitive psychology and human factors, the EHR products themselves create many impediments to clinical workflow, which we enumerate and define here.

*EHR systems are electronic filing cabinets*

Complex interfaces and navigation render searching for, accessing, and organizing relevant information within EHRs difficult. Lack of consistency from one EHR system to another further impedes clinician access to content. Current generation EHRs adopted the mouse/keyboard interface, analog text-based documentation models, and complex paper-derived data representations available when they were designed, which require clinicians to “navigate deeply nested menus and browse through long pull-down lists that are neither filtered nor contextualized.”[39] Data is entered bit by bit requiring multiple keystrokes, points, clicks, and scrolls and utilizing highly trained clinicians as data entry clerks. One study measured an average of 216 mouse clicks or wheels and 729 keyboard clicks per 20-minute patient visit.[40] A number of studies also indicate that increased time interacting with the computer is strongly associated with decreased patient satisfaction.[19,40,41]

*Low usability interface design*

Information in EHRs is often not organized or aligned with the physician’s mental model of care and is not optimized to support clinical decision making. Clicking, scrolling, switching between paths and screens, and counterintuitive data presentations make it challenging to access and process important data.[42] Critical information is often obscured in a plethora of less important text or values.[43,44] Locating and importing data from outside a clinician’s own health system requires extensive effort by the user, when it works at all,[45] raising concerns that the available information represents only a narrow and incomplete view of the patient. Nearly 60 percent of ambulatory care providers report being dissatisfied with their EHR due to workflow and usability concerns,[43] and 72 percent of primary care physicians (PCPs) think that improved interface design is necessary to improve inefficiencies and reduce screen time.[46]

*Document exchange rather than data interoperability*

Analysis of the new-found emphasis on “interoperability”[45] suggests most interoperability efforts focus on improving document exchange and not discrete data exchange or consistent interoperable semantic meaning. As noted above, a significant volume of currently exchanged document content is of low value to clinical care and augmenting document interchange without documentation reform may increase, rather than address clinician burden. There is a foundational need to identify and specify core clinical data, standards, and vocabularies that enable the national objectives of a healthcare ecosystem that is semantically and syntactically interoperable “*without requiring extra user input or ‘special effort’.”*[47]

*EHR systems dictate clinician workflows*

Sixty percent of PCPs think EHRs need a complete overhaul, and only eight percent say the primary value of their EHR is clinically related.[46] Current EHRs have proprietary source codes designed with “one size fits all” workflows, consisting of generic tasks and steps which do not accurately reflect clinicians’ mental models or the way they actually provide care at the bedside and in the clinic.[48,49] Including a wide spectrum of clinical specialties, environments, and contexts in a few common pathways produces systems which force physicians to alter their preferred workflow and cognitive style, which are based on years of training and clinical practice, to align with the EHR’s requirements. The mismatch causes physicians to perceive their EHRs as disruptive and inefficient.[48]

*Overly simplified algorithmic interface design*

In general, current generation EHRs apply a rationalized model of healthcare represented as algorithmic sequences of care delivery choices. In reality, clinical care is iterative and rarely linear. Physicians continuously reformulate goals, revise tasks, and reorder sequences as they acquire new information, interact with individual patients and clinical colleagues, and encountered clinical constraints.[48] Physician workflows are inherently complex, nonlinear, and dependent on a wide variety of data inputs. Physician workflows differ significantly between specialties, between individual providers, between clinical scenarios, diagnoses, and locations, and even between patients for a single provider. For example, one detailed study of two patient visits by 10 PCPs in 10 different primary care centers observed no single or even common workflow pattern. The order and prevalence of task categories varied through the time course of a visit, with the PCPs collecting data throughout the visit.[50] Another study of 55 Emergency Department physicians at four sites using two different EHR products showed wide variability in task durations, ordering, clicks, and accuracy when completing basic EHR functions across EHR products from the same vendor and between products from different vendors.[51]

Clinical workflows are frequently interrupted, for example, by emergencies, phone calls, and/or the need for information not yet available in the electronic record. Time constraints, schedule changes, and revisions in care goals often make it necessary to defer tasks or decisions until more information is available.[48] Current EHR algorithmic designs are encounter-specific without optimal support for resuming work after an interruption. In addition, documentation and other data entry is frequently completed post-encounter at a different time and place, such as afterhours note completion, documentation of phone calls, review and follow-up on laboratory and radiology data, etc. The clinical time consumed by these nonsynchronous processes is not captured by reimbursement regulations and constitutes another major cause of work-life imbalance and consequent physician burnout.

*Ineffective nonspecific Clinical Decision Support (CDS) tools*

A systematic review of twenty-eight randomized trials of CDS systems showed no survival benefit and minimal impact on morbidity.[52] As the medical and scientific knowledge base expands exponentially,[53] physicians and care teams need standardized tools to appropriately navigate and assimilate this information as applied to the complex interrelationships found in patient narrative, physical exam, laboratory data, radiographic images, and care delivery. Current CDS interventions too often take the form of pop-up alerts notifying physicians of warnings such as drug-drug interactions (DDI), drug allergy interactions (DAI), dose ranges etc. Other CDS formats include order sets and either direct links to medical literature or links to guidelines, calculators, or knowledge summaries. Unfortunately, many DDI and DAI tools are interruptive and fail to integrate key pieces of data found throughout the medical record, resulting in large numbers of low value alerts, which lead to “alert fatigue.” The proportion of DDI alerts overridden ranges from 50% to 90% in various studies, with over 60% of the overrides found to be clinically appropriate.[54] Linked literature and knowledge summaries frequently display far more information than needed at the current point in workflow, requiring a long search to find the piece needed to complete the immediate clinical task.[55]

*Lack of context-specific information preprocessing*

Clinicians commonly work under precise and stringent time constraints in demanding environments. Excessive choices create uncertainty and distraction leading to errors. Existing EHR systems are not currently designed to identify what clinical process is underway or parse what data/information is needed at any particular point in workflow. As a result, EHR designers tend to display too many choices, interface links, and other elements to ensure all possible use cases are covered. This creates a system in which “users” become distracted when interrupted and EHR use becomes disorganized and confusing.[56,57] Better mechanisms are needed to retrieve and display information in a context- and/or clinician-determined manner.[45]

*Insufficient support for critical nursing functions*

In various settings, nurses spend anywhere from 22% to 33% of patient care time in medication related activities.[58,59] Researchers have found current barcode medication administration systems (BCMA) can interfere with nurses’ problem-solving, ability to integrate medication administration with other care activities, and ability to collaborate and share workload.[60,61] The lack of context specificity and standardization in EHR care transition tools challenges the nurse to efficiently spot trends in data over time, effectively summarize data for communication across organizations or service lines, and accommodate variation in nursing knowledge and experience.[62,63] Nursing documentation is crucial in the clinical process, for communicating with other care team members, for establishing comprehensive care plans, and for recognizing trends in patients’ needs and clinical condition. Yet a recent study found that nearly a fifth of patient files contained inaccurate medication dose documentation, nearly a third showed one or more care orders was fulfilled late, and in nearly half, nursing patient documentation was partially missing.[64] Another study identified perioperative documentation, including perioperative nursing notes, as a source of communication failures among providers.[65]

**Ideas and New Perspectives for Reducing Burden**

**Extrinsic Burdens**

Serious underlying problems with the economic and social framework of the healthcare system and the culture of medicine interact with and are amplified by the limitations of the EHR. Healthcare leaders, administrators, policy makers, and regulators must commit to comprehensively updating practices and standards so clinician workflows, mental models, and care plans are accurately represented in EHRs and CDS tools which more effectively support clinical workflow.[25]

*Reform clinical documentation regulations*

Two recent studies show that physicians in the US spend nearly two hours on EHR documentation and clerical work for every hour of face time with patients.[7,8] Comprehensive regulatory reform is indispensable to reducing the impact of reimbursement regulations and policies on physician workflows. Healthcare systems in other industrialized countries are often cited for the ability to provide higher quality, more cost-effective care compared to the US. Interestingly, clinical documentation in countries demonstrating higher quality, cost-effective care largely omits the reimbursement and regulatory information that bloats American clinical notes, resulting in documentation which is, on average, four times shorter than that in the US.[30]

According to the American College of Physicians, “The primary purpose of clinical documentation should be to support patient care and improve clinical outcomes through enhanced communication.”[20] Selecting which data to present at a particular point in care and organizing it such that the clinical thinking is easily consumed and understood by the rest of the care team is a complex, variable, context-dependent process.

Many sections of a patient’s medical history (specialty specific problem list, allergies, past medical history, family and social history, review of systems) change very slowly and are already present in the EHR. The patient’s medical history should not be redundantly included, either in whole or in part, in every note. Only certain values or trends in a laboratory panel or sections of a radiology report are typically pertinent in the context of the current encounter. Entering the entire panel or report is distracting and confusing to the reader. The encounter note author should be allowed to enter a discrete value or trend summary compressed and filtered to be meaningful. Physicians understand the meaning of “normal physical exam” and “normal laboratory panel,” and should be allowed to document by variance from the norm when appropriate. Including extraneous documentation of normal findings and associated metadata may often obscure more pertinent information and decrease the quality of care.

The CMS 2021 changes proposed for the Common Procedural Terminology (CPT) E&M guidelines represent a regulatory simplification that could potentially help eliminate some burdens.[26] In that system codes are based on medical decision making (MDM) or time, and specific elements of the history and physical exam do not contribute to coding. However, the rule only applies to outpatient E&M services covered by Medicare. Such rule changes allow reduction in EHR burden but do not guarantee burden reduction will occur. Without corresponding changes for other sites of service (inpatient, emergency department, etc.) and for private payers, fundamental changes in EHR documentation templates are unlikely to evolve.[26,66] While new CMS definitions may aim to make the determination of MDM more rational, significant uncertainties remain. The definition of time as “total physician/qualified health professional (QHP) time on the date of service” does not clarify how working after office hours to complete EHR documentation/note entries and review ancillary data (e.g., laboratory, radiology) will factor into the time determination.[66]

Within the next few years, defining the content and quality in clinical notes must be returned from payers and regulators to practicing physicians, clinical specialty societies, and medical educators, who have the most training and knowledge to make these determinations. The outcome stakeholders must focus on developing evidence-based, context-specific, specialty-specific models and templates which guide and support clinicians in streamlining core documentation to contain only the essential data needed for high quality healthcare and team communication.[30,35]

*Reform non-clinical documentation regulations*

Monitoring and improving care quality, assuring physicians meet appropriate standards of care, confirming care documented as provided is commensurate with charges, and collecting structured, computable clinical data as the basis of a learning healthcare system are achievable goals. However, if we are to achieve needed improvements in the healthcare system, physicians must be free to focus on the patient and on clinical care, not on administrative, regulatory, and financial processes much less relevant to clinical care. The new goals must be to simplify, harmonize, and automate all nonclinical documentation and administrative responsibilities. In supporting clinical care delivery, EHRs should submit all information needed for routine preauthorizations and insurance company determinations without clinician intervention. Regulatory incentives for payers to create a dedicated language or interface portals to handle authorization transaction sets should be implemented. The HL7 Da Vinci Project is already working to develop such transaction sets based on the HL7 FHIR standard.[67,68] Within the next few years, EHRs, as a condition of certification, should record, aggregate, and submit other required non-clinical data, (e.g., quality improvement data, federal EHR usage data, public health syndromic surveillance data, etc.) without clinician intervention, although other staff members might help with this process. If medicolegal issues arise about whether standards of care have been met or charges are justified, the audit trail should be capable of tracking what data was reviewed, how much time was spent in each section of the EHR, and any other information necessary to answer those questions.

*Close the gaps in regulation of EHR software development*

UCD processes must be applied more rigorously, consistently, and transparently. EHR developers should be required to document the details of their UCD methods and to demonstrate that team members with human factors/usability expertise are involved in product development.[36] Consensus reproducible measures of health IT usability and safety should be developed, based on plausible use case testing scenarios applied in both formative (during software development) and summative (implemented products at healthcare organizations) contexts.[35] EHR system functional standards have been used successfully in the past to specify system behavior. Similarly, functional requirements and standards for usability, implemented through certification programs or other national health IT strategies, could contribute to improving EHR usability.[69] Work on such an “EHR usability functional profile” is already in progress at HL7.[70]

Results from scenario-based testing would encourage market competition based on observed quality in real practice settings and drive the rounds of iterative improvement that form the heart of UCD, although the extremely high cost of changing EHR products will still create persistent barriers to this process. Consensus specialty-specific standard scenario libraries agreed on by clinicians, developers, researchers, regulators and healthcare organizations could form the basis for consistent usability certification testing and monitoring progress in this area.[35] Finally, support mechanisms which enable experienced physicians and nurses to participate in usability testing by allowing job flexibility and replacing income lost due to time consumed in such testing are sorely needed.

An effective approach to preventing problems related to clinicians’ use of multiple EHR systems in different contexts would be the development of interface-level design specifications supported by evidence-based principles of human-computer interface (HCI) design.[35] Utilizing such platform conventions to enable a familiar “look and feel” in different contexts has been very successful for improving safety in both the automotive and aviation industries. EHR developers have consistently argued that such standards would stifle innovation, but examples from other industries do not support this claim.[35,36] The ONC discussed this in its 2018 draft strategy on reducing clinician burden and would be well positioned to lead the effort.[45]

Many health IT contracts between developers and organizations contain “hold harmless” clauses[71] that protect developers from liabilities and intellectual property protections (“gag clauses”) that prevent sharing of screenshots and other material which would help with problem solving. Such contract elements prevent developer accountability and impede the root cause analysis of safety problems. They should be prohibited. Policy makers, for example, the Office of the National Coordinator, should also support creation of a national usability and safety database where clinicians can freely report, illustrate, and share usability and safety issues and compare experiences[35] and where reports can be investigated as appropriate, similar to programs in place at the National Transportation Safety Board or the US Food and Drug Administration. Such a database would emphasize that improving health IT quality and safety is a *shared responsibility,*[72] and it could be accomplished while still addressing developer concerns about intellectual property.[35]

*Address the root causes of organizational stress and moral injury*

Healthcare organizations have so far taken two major approaches to the problems of clinician distress and burnout. The first is to implement intensive team based approaches aimed at training physicians to use existing EHR functionalities more efficiently, building new specialty-specific EHR configuration adjustments and tools, and redesigning clinical workflows.[73] The second is to implement physician wellness and resiliency programs focusing on mindfulness, meditation, exercise, sleep hygiene, and other well established stress management techniques from the psychology literature.[37,74] Although these interventions have significant value and provide some short term relief, they are not long term solutions because they do not address the root cause of clinician stress and burnout. The very term “burnout” suggests that the problem originates in the clinician, who somehow lacks the personal resources or resiliency to bear up against the pressures of the work environment. In fact, most healthcare organizations do not fully practice their stated values, and the reality of practice misaligns with clinicians’ deeply held commitment to putting the patient first.[37,74] Dean and coworkers have therefore suggested that the term burnout should be reframed as moral injury, which “describes the challenge of simultaneously knowing what care patients need but being unable to provide it due to constraints that are beyond our control.”[37]

On average, patients are sicker these days, with increasing number and severity of chronic conditions. No amount of EHR tweaking or yoga will solve the problems of declined preauthorization for vital treatments, inadequate time to discuss complex diagnoses, treatments, and patient emotions, and responding to a computer system that relentlessly favors metrics and data entry over communication.[37] The economic framework of the healthcare system constantly pressures clinicians to consider the payer, the EHR, the hospital, and the healthcare system along with the patient and punishes them when their productivity metrics don’t confirm that they are indeed considering all those priorities. Is that really the road to patient-centered care? The root cause of individual distress is found in a broken healthcare system, not in the deficiencies of individuals.[37]

Since 1975, the number of healthcare administrators has increased more than 1,500 percent,[75] and there are now about 10 administrators for every physician.[76] The productivity metrics governing physician evaluations are written by industrial efficiency engineers who have never taken care of a patient. It is critical for clinicians and healthcare administrators to communicate more honestly and transparently about balancing the priorities of healing versus profit, about acknowledging the value of the time clinicians and patients spend together, and about creating a system that values empathy and compassion and truly supports its clinicians’ commitment to always make their patients’ best interest the highest priority.[37] As with clinical documentation, the process of redesigning workflow, improving the efficiency of EHRs, determining the time needed for clinical processes, and establishing evidence-based, specialty-specific productivity metrics should include extensive input from practicing clinicians, medical specialty societies, and medical educators. Clinician stakeholders must also put aside competition and reestablish mutual support, mentorship and activism in advocating for fundamental changes that will be both expensive and difficult to implement.[37]

**Intrinsic Burdens**

EHRs rely too heavily on simply representing paper-based standards and on forcing clinicians to conform to a rigid, idealized image of workflow that often bears little resemblance to actual clinical practice. It will take disruptive innovation to progress beyond these limitations and create systems that accommodate the inevitable variability in patient care and more effectively support clinical workflow.

*Rethink user-centered design*

Individual patients are remarkably variable on multiple levels. Studies of Medicare beneficiaries with multiple chronic conditions found over 2 million combinations of 70 disease categories in 32 million Medicare beneficiaries.[77,78] The number of comorbidity combinations would be even higher if calculated at the level of individual ICD codes. In addition to complex patterns of comorbidities, patients differ significantly in ethnic, genetic, molecular, and socioeconomic characteristics, in response to drugs and treatments, and in personal values and preferences. When comparing and grouping medical histories for the purposes of informing care, most patients belong to a small (if not unique) subgroup. How does UCD converge to a solution when the dimensionality of the problem is so high? Current paradigms for implementing both EHRs and clinical measurements for quality purposes are not designed for this level of complexity and disease granularity.[79,80] Current application of UCD targets care of mythical “average patients,” not real human beings.

Commitment to patient-centered care requires physicians to confront this individual variability as they diagnose and treat each patient, resulting in highly variable workflows and many unarticulated (sometimes unconscious) thought processes, which are more likely to be individualized than shared by most users in the field (see above). No matter whom a design team elects to study, the healthcare IT being developed will inevitably be based on the experiences, interactions, and constraints of a small percentage of the total users,[56,57] and the results may not reflect the needs of the wider user base. In addition, careful *in situ* observation to document real workflows is impeded by complex, time-constrained clinical environments and by privacy regulations and concerns. Testing in artificial environments and relying on surveys or participants’ descriptions rather than real-world observation of the work can miss important aspects of users’ interactions with a system. This paradox of UCD was well demonstrated by Hultman et al. who undertook a redesign of the ambulatory navigator function of a major vendor EHR with the goal of improving usability and clinician satisfaction.[81] Even though the well-designed project incorporated every known UCD best practice, the results showed no usability improvement at all. The perceived workload and overall satisfaction were the same for both designs, and navigation patterns in either design were highly variable across participants, as were participants’ choices of which system they would prefer to use.

UCD practices work well for optimizing commercial and industrial IT designs because the processes being supported are relatively constant and well understood; the options at each step are somewhat constrained, thus the number of decisions is manageable. Clinical processes must accommodate a wide range of data types in support of an enormous range of users performing varying, highly individualized sequences of high complexity tasks, caring for highly individual patients, often with incomplete data.[82] Applying usability research methods to EHR design assumes there is a standard or optimal way of thinking about each clinical process at a very granular level, yet no such standard exists. In fact, most clinical processes are context-dependent and have never been thoroughly mapped or understood,[83] and physicians approach them with highly variable mental models and cognitive styles. It seems unlikely that any amount of usability research can derive a single consensus “one size fits all” interface model acceptable to a large proportion of physicians, even in a single specialty. On the other hand, a new approach to UCD, deployed across multiple specialties at a more granular and localized level, could be quite valuable to identify the information physicians need for optimal function within new, flexible, context-aware frameworks.

A more location- and context-specific application of UCD was demonstrated by Bishop et al.[84] who used a library of interface functions invoked using a drag and drop interface builder. Using this design tool, a small team of clinicians and one or two engineers was able to totally control the design, appearance, and operation of every aspect of a model clinical information system for the Emergency Department (ED) at a single hospital. The design outputs were rapidly (overnight) and automatically compiled into an operational clinical information system executed in a Web browser. Through iterative testing and revision (UCD) the team converged on a system optimized for its particular workflows, data flows, and screen layouts from the ground up.[84] Such a process could iterate rapidly because the software enabled near real-time generation of a run-time system. Primary control by a user-led design team would increase the ability to identify and incorporate context-specific information flows and displays and rapidly implement improvements in response to new clinical challenges. Research to increase the granularity of UCD methods and enable developers to use clinician-led design teams should receive strong support. It is important to note that developing more individualized interfaces and workflows can still be compatible with the presence of safety “guardrails” within systems and with the ability of developers to innovate.

*Rethink the EHR interface design paradigm*

Current EHR human-computer interfaces (HCI) continue to adopt visually complex representations derived from prior paper-based records. The current WIMP (Windows, Icons, Menus, Pointers) form-based data entry paradigm, little changed from Windows 95, “requires clinicians to navigate deeply nested menus and browse through long pull-down lists that are neither filtered nor contextualized.”[39] Data is entered one bit at a time requiring multiple keystrokes, points, clicks, and scrolls. An important lesson of the last 10 years is that physician-patient interactions and physician physical and cognitive workflow processes are not orderly or linear enough to be well accommodated by current algorithmic methods and client server architectures, and the mismatch causes many adverse consequences.[48]

Requiring physicians to allot ever increasing amounts of time for EHR training in an attempts to modify their thought processes and workflows to predetermined systems will not improve quality of care or decrease burnout. Rather, designers should be required to produce more flexible, modular systems that may be adapted to individual mental models and cognitive styles.Disruptive innovation and real progress will require EHRs to evolve from data-centric transactional systems (electronic filing cabinets) to process-centric workflow systems, designed from the ground up to be flexible and context-aware and to provide “just in time” delivery of exactly the data and functionality the physician needs at the current point in workflow. EHRs are tools, and should adapt to their users, not the other way around.

Systems must also accommodate the inevitable variability involved in clinical practice and be adjustable to fit new clinician needs on the fly. Instead of requiring physicians to fetch each piece of information from different drawers of the filing cabinet one by one, EHRs must assist in aggregating, organizing, and presenting relevant context-specific information to the clinician. Other members of the care continuum (e.g., trained medical assistants and especially patients) should be more actively included in the documentation and data entry process, freeing clinicians to keep their full attention focused on clinical care and communication. Team based care must be based on workflow-integrated data capture supported by multiple members of the care team, each working at the “top of his license.” Much of the data captured should be structured based on defined terminologies and data standards which enable semantic interoperability, data persistence, and access to data via application programming interfaces (APIs).[85,86] The current trend of utilizing scribes for data entry is another example of this approach, although the use of scribes increases costs, may inhibit physician-patient interactions, and may add a layer of privacy and security concerns.[87,88]

*Utilize application programming interfaces (APIs)*

API technology certification criteria were introduced as part of ONC’s *2015 Health IT Certification Criteria*,[89] but this technology has so far been viewed as a method to facilitate consumer access to healthcare data and provider ability to access, integrate, and report required regulatory data such as electronic clinical quality measures (eCQMs). EHR developers should be required to provide robust general-purpose APIs (and associated development platforms) allowing the use of innovative, pluggable, interchangeable apps created by physicians, healthcare organizations, and many other sources and not dependent on particular EHR products or versions.[90] Based on developer resistance so far, this will only be accomplished by strong regulatory incentives. Industry standard APIs could be based on the Substitutable Medical Apps And Reusable Technology (SMART) on Fast Healthcare Interoperability Resources (FHIR) platform[68] enabling the development of an “apps-based information economy,”[91] where interested professionals from many disciplines, including physicians, can develop programs which fill gaps in current EHR functionality and provide a more tailored end user experience. Work on this approach has already been started as The HL7 Argonaut Project.[92] Such work should receive much more vigorous financial and regulatory support.

*Implement interface level design specifications*

As noted above, many clinicians already use multiple health IT systems, and dealing with multiple differing interface designs, icon sets, and workflow steps can conceivably create additional safety and usability challenges.[36] An effective approach to mitigating such problems would be the development of interface-level design specifications supported by evidence-based principles of human-computer interface (HCI) design.[35,36] Utilizing such platform conventions to enable a familiar “look and feel” in different contexts has been very successful for improving safety in both the automotive and aviation industries. EHR developers have consistently argued that such standards would stifle innovation, but examples from other industries do not support this claim. Again, it is a shared responsibility of developers, clinicians, user experience (UX) experts, researchers, and regulators to collaborate in developing standards to improve EHR usability and safety.[35] The ONC discussed this in its 2018 draft strategy on reducing clinician burden[45] and would be well positioned to lead the effort.

*Develop innovative models for CDS tools*

Effective CDS must provide the right information to the right person in the right CDS intervention format through the right channel at the right point in workflow,[93] by developing improved human computer interfaces that support rather than interrupt workflow. Using artificial intelligence to properly incorporate data already in the EHR into trigger algorithms and redefining the severity level where alerts are interruptive would decrease the number of low value alerts. CDS tools must show the clinical user the underlying data and rationale leading to a recommendation, at a user-selectable level of detail, and allow the user to immediately act on the information. CDS systems should make it easy for users to provide feedback on the accuracy and clinical utility of alerts to be used in iterative rounds of system optimization. Finally, CDS should not have to be created as a one-off in every new implementation.Regulators (such as the ONC) should support the creation of internet accessible CDS repositories of validated, curated CDS knowledge modules and basic operational components (triggers, notifications, etc.) available as standard sets and templates.[94]

*Uncouple the data model from the interface*

Currently, patient representations (the body of information representing a patient’s medical history and current medical status) exist mainly within siloed EHRs. Interoperability is suboptimal, and representing a patient from the perspective of one EHR will invariably be limited. An emerging consensus finds that it would be superior to define and use a canonical, common patient data model (CPDM) to serve as the reference point for constructing and aggregating all patient data into an optimal representation for end-users.[95] Such models would be stored in a “patient cloud,” and EHRs would access and synchronize with them using a standard interface, termed a “clinical portal.” The availability of the canonical model in a patient cloud external to EHRs could allow clinical judgment and clinical actions to be based on complete, up-to-date patient centered information, regardless of site or time of service. This is the definition and purpose of full interoperability. Patients would assume full control over the privacy and sharing of their data, and knowledge about healthcare would be provided to help them interpret the data in the models. Such functions would be provided by new and improved “patient portals” different from the clinical portals and from current EHR-tethered patient portals. Patient data maintained in its own independent system could be obtained via a single query to a single record custodian and a single patient account, rather than the complexity of a broadcast query to multiple health information networks and potentially thousands of devices. Defining and standardizing a reference architecture for CPDMs and demonstrating a reference implementation would be a major contribution to accelerating progress towards this solution and should be strongly supported.

*Allow users to customize data representations*

Another approach to achieving the flexibility needed to support highly variable clinician workflows is the development of widget based EHR interfaces. A “widget” is defined as a single draggable window containing exactly the data selected by a particular physician. A widget could contain a lab panel, text from a note or report, a graph of lab results, or a radiographic image, and custom widgets could be created by dropping individual chunks of information onto a blank widget. A physician could populate one or more screens, in real time, with exactly the widgets needed at a particular point in workflow and save them for reuse and sharing with others.[96] Screens composed of information elements selected or created by the user increase the chance that all relevant items are on screen and exclude distractions, decreasing keyhole effect and reducing the need for screen transitions. Externalizing some of the information the user has to consider utilizes distributed cognition to reduce cognitive load. Spatially arranging the elements to construct a representation which better fits the user’s mental model and/or the external features of the task (e.g., problem priorities, diagnostic categories) facilitates clinical thinking and decision making.[96] Widget based interfaces and workflow managers implemented locally and interacting with data stored as CPDMs in the cloud could form the basis for appropriately flexible EHRs[97] which can adapt to end users on the fly and evolve new functionalities much more quickly than current products.

*Incorporate machine learning and artificial intelligence*

The most promising long-term approach to improving clinical workflow, but also the most technically challenging, is the application of natural language processing (NLP), machine learning (ML), and artificial intelligence (AI) methods. Current NLP systems already exceed the performance of human transcriptionists, but speech capture alone does not solve the problems, because the clinician still has to select excerpts from unstructured text and synthesize them with other clinical data to achieve logical structure and narrative interpretability. Entering data with mouse and keyboard remains inherently slow, frustrating and “clunky.” [98-100] What clinicians need is an AI enabled voice command interface which can parse the topics covered in the encounter. Such context aware AI could then become IA (an intelligent assistant), designed to collect, sort, and present clinical information related to those topics from multiple sources (previous notes, laboratory results, radiology reports, pharmacy records, etc.), organized to support clinical thinking and decision making.[99,100] The postulated IA would also semantically search relevant scientific literature to present real-time evidence-based recommendations such as differential diagnoses, suggested evaluations, risk calculations and clinical guidelines.[100] The extra workflow support could help free physicians’ active listening and engagement capabilities and help restore patients’ sense of empathy and connection.[98]

The deep neural networks employed in ML contain many hidden layers and are proficient at recognizing patterns not discernible to humans. They are also narrow, require well-formed data, and are prone to error in contexts that do not precisely fit their training data sets.[98] Neither the networks nor their designers can explain how the system arrives at its predictions in a manner comprehensible to a human being, creating the aptly named “black box” problem.[101] In the healthcare domain, the consequences of AI-related errors could be life threatening. Most physicians, and also most patients, would be appropriately uncomfortable making medical decisions based solely on the recommendations of even the most sophisticated ML system. It is therefore vital to design AI enhanced systems as partners to human practitioners and enable them to present information and recommendations in a non-disruptive way that decreases cognitive load and enhances clinician reasoning. Work on such intelligent assistants, termed “autoscribe AI” has already been initiated at Stanford University Medical Center in collaboration with Google.[99] Work on algorithms to support clinician workflow and automate documentation is also in progress at Microsoft, Amazon, Nuance, Google, and multiple startups.[98]

Interestingly, these concepts are not new. In 1970 William Schwartz wrote in the *New England Journal of Medicine*:[102]

*Indeed, it seems probable that in the not too distant future the physician and the computer will engage in frequent dialogue, the computer continuously taking note of history, physical findings, laboratory data, and the like, alerting the physician to the most probable diagnoses, and suggesting the appropriate, safest course of action.*

That we are just now, nearly 50 years later, achieving the computational power to seriously pursue this goal shows how difficult the problem is. However, computational power alone is not enough. Even if the system can synthesize unstructured language and multiple disparate clinical data types into a succinct note, nonverbal interactions will be missed and knowing that the encounter is being recorded and archived will likely affect clinician and patient behavior and interactions.[98] Despite the enormous resources and work necessary to make progress, strong research support directed at incorporating AI into medical practice is justified by the potential gains.

**Conclusions and Lessons Learned**

**Technology alone is not enough**

Bedside clinical medicine is an intensely human endeavor, and many of its most important components are uniquely human and nonquantifiable. In the foreseeable future, it is unlikely machines will be able to provide empathy, compassion, and emotional support, to reason under conditions of uncertainty and incomplete data, to integrate and resolve conflicting values and priorities, to use insight and imagination to create completely new and worthwhile concepts, or to inspire the trust and confidence necessary to heal individual humans or lead human teams. Information technology solutions cannot, by themselves, improve the quality of care, especially as they are currently employed to pressure clinicians, enforce narrowly defined productivity goals, and maximize profits.[37,98] The goal of health IT is not to create an ever-accelerating healthcare assembly line, but to utilize machines’ special strengths (such as finding patterns in big data sets, summarizing huge volumes of research literature, never becoming fatigued or distracted) to accomplish some of the routine, quantitative elements of care more efficiently and free clinicians to focus their attention and concentration on the transrational components of care which only humans can provide and on supporting and bonding with their patients.[98]

**Information technology must partner with, not dictate to clinicians**

Based on limited but reasonably convincing data that the broad implementation of health IT would improve healthcare quality and cost efficiency[1,103], policymakers and regulators instituted substantial positive and negative incentives that drove the rapid adoption of these systems. Development was focused on meeting the requirements of EHR certification rather than clinical functionality or usability, and the commercial products were based on the systems and paradigms available at the time they were designed. The policies were well intended and aimed at valid social and scientific goals, but were fraught with many unexpected and unintended consequences, as evidenced by our experiences over the last ten years.[16,104]

In our haste to implement EHRs and meet the regulatory requirements, systems were not optimized to support real bedside clinical workflows and did not adequately incorporate the large existing body of knowledge about human factors and human safety engineering. As a result, we failed to achieve the right balance between clinicians, patients, and machines, and we created a path leading to widespread clinician burnout and patient dissatisfaction.[98] The rise of EHRs also amplified the distortions caused by the inherent conflict between our for-profit healthcare system and our stated ideal of patient-centered healthcare for the common good.

For health IT to achieve its goals, it must be re-envisioned and redesigned to achieve a full partnership where clinicians can comfortably utilize machines’ speed, accuracy and predictive power (all demonstrably better than that of humans) to increase the time available for explanation, thinking, decision making, and better patient understanding of and participation in the decisions ultimately made.[105] To paraphrase Verghese and colleagues, “Only a combination of well-informed, empathetic physicians and sophisticated predictive tools that free them from clinical workflow burdens and help them focus on patients and reason more accurately will enable the high quality, patient-centered, cost-effective healthcare system clinicians desire and society needs.”[105]

**Overcoming the barriers to innovation is everyone’s responsibility**

Alleviating clinical workflow burdens will be extraordinarily challenging. Problems with technical complexity, high development costs, patient privacy, legal ramifications of system-related errors, unavoidable “black box” problems[101] associated with AI and deep ML, and many other issues must be solved. Clinicians, policy makers, and regulators must also open more honest and transparent lines of communication about the economic framework of the healthcare system.[37] The same economic distortions that cause the US to spend twice as much per capita on healthcare as other industrialized countries also impede our efforts to improve the functioning of health IT and to improve the daily experiences of patients and clinicians. One thing is absolutely clear. Incremental tweaks based on the current paradigm may be of some help, but will not suffice to achieve the long-term goal. Building the healthcare system of the future will require huge investment in clinical and academic health informatics research and comprehensive regulatory reform which frees physicians and EHR developers from current constraints and provides powerful incentives for them to explore new frameworks and more novel, creative solutions, some of which are reviewed above.

Many stakeholders may argue that the concepts expressed here are too radical, too aspirational, too expensive, too revisionist, too risky in abandoning sunk costs, and too disruptive to traditional medical frameworks. Yet progress based on our current efforts has been glacially slow, and it seems highly unlikely that we will achieve a better quality, more patient-centered, safer, more cost-effective healthcare system without radical reform and a new vision. The lesson of the last decade in health IT is that only disruptive innovation will get us where we need to go. It is the shared responsibility of clinicians, health IT professionals, EHR developers, researchers, user experience professionals, healthcare administrators, and regulators to overcome inertia, stand up to vested interests, and do whatever it takes to put the patient back at the center of the healthcare system.[98]

On September 12, 1962 in a speech at Rice University, President John F. Kennedy said:[106]

*We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one we intend to win.*

On July 20, 1969 Neil Armstrong said, “That’s one small step for [a] man, one giant leap for mankind.”[107] We will likely never again see the level of resources and national commitment that went into the Apollo Program. However, as annual US healthcare costs approach 20% of GDP, nearly twice the level of most other industrialized nations, it seems reasonable to ask whether putting our healthcare system on a new and better path isn’t every bit as important as beating the Russians to the moon.

**References**

1. Hillestad R, Bigelow J, Bower A, et al. Can electronic medical record systems transform health care? Potential health benefits, savings, and costs. *Health Aff (Millwood).* 2005;24(5):1103-1117.PMID: 16162551.DOI: 10.1377/hlthaff.24.5.1103

2. Lee J, Kuo YF, Goodwin JS. The effect of electronic medical record adoption on outcomes in US hospitals. *BMC Health Serv Res.* 2013;13:39.PMID: 23375071.DOI: 10.1186/1472-6963-13-39

3. Yanamadala S, Morrison D, Curtin C, et al. Electronic Health Records and Quality of Care: An Observational Study Modeling Impact on Mortality, Readmissions, and Complications. *Medicine (Baltimore).* 2016;95(19):e3332.PMID: 27175631.DOI: 10.1097/MD.0000000000003332

4. Roser M. Link between health spending and life expectancy: US is an outlier. 2017; <https://ourworldindata.org/the-link-between-life-expectancy-and-health-spending-us-focus>. Accessed December 30, 2019.

5. Thakrar AP, D. FA, Maltenfort MG, Forrest CB. Child Mortality In The US And19 OECD Comparator Nations: A 50-Year Time-Trend Analysis. *Health Aff (Millwood).* 2018;37(1):140-149.PMID: 29309221.DOI: 10.1377/hlthaff.2017.0767

6. Center for Medicare and Medicaid Services. CMS National Health Expenditure Data. 2019; <https://www.cms.gov/research-statistics-data-and-systems/statistics-trends-and-reports/nationalhealthexpenddata/nationalhealthaccountshistorical.html>. Accessed December 30, 2019.

7. Sinsky C, Colligan L, Li L, et al. Allocation of Physician Time in Ambulatory Practice: A Time and Motion Study in 4 Specialties. *Ann Intern Med.* 2016;165(11):753-760.PMID: 27595430.DOI: 10.7326/M16-0961

8. Arndt BG, Beasley JW, Watkinson MD, et al. Tethered to the EHR: Primary Care Physician Workload Assessment Using EHR Event Log Data and Time-Motion Observations. *Ann Fam Med.* 2017;15(5):419-426.PMID: 28893811.DOI: 10.1370/afm.2121

9. Shanafelt TD, Dyrbye LN, Sinsky C, et al. Relationship Between Clerical Burden and Characteristics of the Electronic Environment With Physician Burnout and Professional Satisfaction. *Mayo Clin Proc.* 2016;91(7):836-848.PMID: 27313121.DOI: 10.1016/j.mayocp.2016.05.007

10. Gardner RL, Cooper E, Haskell J, et al. Physician stress and burnout: the impact of health information technology. *J Am Med Inform Assoc.* 2019;26(2):106-114.PMID: 30517663.DOI: 10.1093/jamia/ocy145

11. National Academy of Medicine. *Taking Action Against Clinician Burnout: A Systems Approach to Professional Well-Being.*DOI: <https://doi.org/10.17226/25521>. Washington, DC: The National Academies Press; 2019.ISBN: 978-0-309-49547-9

12. Cebul RD, Love TE, Jain AK, Hebert CJ. Electronic health records and quality of diabetes care. *New England Journal of Medicine.* 2011;365(9):825-833.PMID: 21879900.DOI: 10.1056/NEJMsa1102519

13. McCullough JS, Christianson J, Leerapan B. Do electronic medical records improve diabetes quality in physician practices? *The American journal of managed care.* 2013;19(2):144-149.PMID: 23448111.

14. Soumerai SB, Starr D, Majumdar SR. How Do You Know Which Health Care Effectiveness Research You Can Trust? A Guide to Study Design for the Perplexed. *Prev Chronic Dis.* 2015;12:E101.PMID: 26111157.DOI: 10.5888/pcd12.150187

15. Belden JL, Grayson R, Barnes J. *Defining and Testing EMR Usability: Principles and Proposed Methods of EMR Usability Evaluation and Rating.* Chicago, IL: HIMSS EHR Usability Task Force;2009

16. Kellermann AL, Jones SS. What it will take to achieve the as-yet-unfulfilled promises of health information technology. *Health Aff (Millwood).* 2013;32(1):63-68.PMID: 23297272.DOI: 10.1377/hlthaff.2012.0693

17. Committee on Patient Safety and Health Information Technology IoM. *Health IT and Patient Safety: Building Safer Systems for Better Care.* Washington, D.C.: National Academies Press;2012.PMID: 24600741

18. Sittig DF, Singh H. A new sociotechnical model for studying health information technology in complex adaptive healthcare systems. *Qual Saf Health Care.* 2010;19 Suppl 3:i68-74.PMID: 20959322.DOI: 10.1136/qshc.2010.042085

19. Farber NJ, Liu L, Chen Y, et al. EHR use and patient satisfaction: What we learned. *Journal of Family Practice.* 2015;64(11):687-696.PMID: 26697540.

20. Kuhn T, Basch P, Barr M, et al. Clinical documentation in the 21st century: executive summary of a policy position paper from the American College of Physicians. *Ann Intern Med.* 2015;162(4):301-303.PMID: 25581028.DOI: 10.7326/M14-2128

21. Erickson SM, Rockwern B, Koltov M, et al. Putting Patients First by Reducing Administrative Tasks in Health Care: A Position Paper of the American College of Physicians. *Ann Intern Med.* 2017;166(9):659-661.PMID: 28346948.DOI: 10.7326/M16-2697

22. HL7 International. Reducing Clinician Burden. 2019; <http://wiki.hl7.org/index.php?title=Reducing_Clinician_Burden>. Accessed December 31, 2019.

23. Agency for Healthcare Research and Quality. What is Workflow? <https://healthit.ahrq.gov/health-it-tools-and-resources/evaluation-resources/workflow-assessment-health-it-toolkit/workflow>. Accessed December 31, 2019.

24. Carter J. Workflow & Process Definitions. 2018; <http://www.clinicalworkflowcenter.com/resources/workflow-process-definitions>. Accessed December 31, 2019.

25. Auerbach AD, Khanna R, Adler-Milstein J. Letting a Good Crisis Go to Waste. *J Gen Intern Med.* 2019;DOI: 10.1007/s11606-019-05552-z.PMID: 31745851.DOI: 10.1007/s11606-019-05552-z

26. Basch P, Smith JRL. CMS Payment Policy, E&M Guideline Reform, and the Prospect of Electronic Health Record Optimization. *Appl Clin Inform.* 2018;9(4):914-918.PMID: 30586672.DOI: 10.1055/s-0038-1676337

27. Payne TH, Corley S, Cullen TA, et al. Report of the AMIA EHR-2020 Task Force on the status and future direction of EHRs. *J Am Med Inform Assoc.* 2015;22(5):1102-1110.PMID: 26024883.DOI: 10.1093/jamia/ocv066

28. Frieden J. Prior Authorization's Pain Continues for Providers. 2018; <https://www.medpagetoday.com/practicemanagement/reimbursement/72071>. Accessed December 31, 2019.

29. Krenn L, Schlossman D. Have Electronic Health Records Improved the Quality of Patient Care? *PM R.* 2017;9(5S):S41-S50.PMID: 28527503.DOI: 10.1016/j.pmrj.2017.04.001

30. Downing NL, Bates DW, Longhurst CA. Physician Burnout in the Electronic Health Record Era: Are We Ignoring the Real Cause? *Ann Intern Med.* 2018;169(1):50-51.PMID: 29801050.DOI: 10.7326/M18-0139

31. Maslach C, Leiter M. Understanding the Burnout Experience: Recent Research and Its Implications for Psychiatry. *World Psychiatry.* 2016;15:103-111.PMID: 27265691.DOI: 10.1002/wps.20311

32. Melnick ER, Dyrbye LN, Sinsky CA, et al. The Association Between Perceived Electronic Health Record Usability and Professional Burnout Among US Physicians. *Mayo Clin Proc.* 2019;DOI: 10.1016/j.mayocp.2019.09.024.PMID: 31735343.DOI: 10.1016/j.mayocp.2019.09.024

33. Ratwani RM, Fairbanks RJ, Hettinger AZ, Benda NC. Electronic health record usability: analysis of the user-centered design processes of eleven electronic health record vendors. *J Am Med Inform Assoc.* 2015;22(6):1179-1182.PMID: 26049532.DOI: 10.1093/jamia/ocv050

34. Ratwani RM, Benda NC, Hettinger AZ, Fairbanks RJ. Electronic health Record Vendor Adherence to Usability Certification Requirements and Testing Standards. *JAMA.* 2015;314(10):1070-1071.PMID: 26348757.DOI: 10.1001/jama.2015.8372

35. Ratwani RM, Reider J, Singh H. A Decade of Health Information Technology Usability Challenges and the Path Forward. *JAMA.* 2019;321(8):743-744.PMID: 30715133.DOI: 10.1001/jama.2019.0161

36. Savage EL, Fairbanks RJ, Ratwani RM. Are informed policies in place to promote safe and usable EHRs? A cross-industry comparison. *J Am Med Inform Assoc.* 2017;24(4):769-775.PMID: 28339697.DOI: 10.1093/jamia/ocw185

37. Dean W, Talbot S, Dean A. Reframing Clinician Distress: Moral Injury Not Burnout. *Federal Practitoner.* 2019;36(9):400-402.PMID: 31571807

38. Ofri D. The Business of Healthcare Depends on Exploiting Doctors and nurses. 2019; <https://www.nytimes.com/2019/06/08/opinion/sunday/hospitals-doctors-nurses-burnout.html>. Accessed December 31, 2019.

39. Street RL, Jr., Liu L, Farber NJ, et al. Provider interaction with the electronic health record: the effects on patient-centered communication in medical encounters. *Patient Educ Couns.* 2014;96(3):315-319.PMID: 24882086.DOI: 10.1016/j.pec.2014.05.004

40. Street RL, Jr., Liu L, Farber NJ, et al. Keystrokes, Mouse Clicks, and Gazing at the Computer: How Physician Interaction with the EHR Affects Patient Participation. *J Gen Intern Med.* 2018;33(4):423-428.PMID: 29188544.DOI: 10.1007/s11606-017-4228-2

41. Asan O, Smith P, Montague E. More screen time, less face time - implications for EHR design. *J Eval Clin Pract.* 2014;20(6):896-901.PMID: 24835678.DOI: 10.1111/jep.12182

42. Beasley JW, Wetterneck TB, Temte J, et al. Information chaos in primary care: implications for physician performance and patient safety. *J Am Board Fam Med.* 2011;24(6):745-751.PMID: 22086819.DOI: 10.3122/jabfm.2011.06.100255

43. Patterson ES, Lowry SZ, Ramaiah M, et al. Improving Clinical Workflow in Ambulatory Care: Implemented Recommendations in an Innovation Prototype for the Veteran's Health Administration. *EGEMS (Wash DC).* 2015;3(2):1149.PMID: 26290887.DOI: 10.13063/2327-9214.1149

44. Schlossman DM, Staggers N. Five Usability Barriers Preventing Health IT From Supporting Clinician Needs. 2016; <https://www.himss.org/news/five-usability-barriers-preventing-health-it-supporting-clinician-needs>. Accessed January 8, 2019.

45. Office of the National Coordinator for Health Information Technology. Strategy on Reducing Regulatory and Administrative Burdens Relating to the Use of Health IT and EHRs. 2018; <https://www.healthit.gov/sites/default/files/page/2018-11/Draft%20Strategy%20on%20Reducing%20Regulatory%20and%20Administrative%20Burden%20Relating.pdf>. Accessed December 31, 2019.

46. Stanford Medicine and the Harris Poll. How Doctors Feel About Electronic Health Records: National Physician Poll. 2018; <https://med.stanford.edu/content/dam/sm/ehr/documents/EHR-Poll-Presentation.pdf>. Accessed December 31, 2019.

47. Rucker DW. Achieving the Interoperability Promise of 21st Century Cures. 2018; <https://www.healthaffairs.org/do/10.1377/hblog20180618.138568/full/>. Accessed December 31, 2019.

48. Karsh BT, Weinger MB, Abbott PA, Wears RL. Health information technology: fallacies and sober realities. *J Am Med Inform Assoc.* 2010;17(6):617-623.PMID: 20962121.DOI: 10.1136/jamia.2010.005637

49. Friedberg MW, Chen PG, Van Busum KR, et al. *Factors Affecting Physician Professional Satisfaction and Their Implications for Patient Care, Health Systems, and Health Policy.* Santa Monica, CA: RAND Corporation; 2013.ISBN: 978-0-8330-8220-6

50. Holman GT, Beasley JW, Karsh BT, et al. The myth of standardized workflow in primary care. *J Am Med Inform Assoc.* 2016;23(1):29-37.PMID: 26335987.DOI: 10.1093/jamia/ocv107

51. Ratwani RM, Savage E, Will A, et al. A usability and safety analysis of electronic health records: a multi-center study. *J Am Med Inform Assoc.* 2018;25(9):1197-1201.PMID: 29982549.DOI: 10.1093/jamia/ocy088

52. Moja L, Kwag KH, Lytras T, et al. Effectiveness of computerized decision support systems linked to electronic health records: a systematic review and meta-analysis. *Am J Public Health.* 2014;104(12):e12-22.PMID: 25322302.DOI: 10.2105/AJPH.2014.302164

53. Van Noorden R. Nature News Blog: Global Scientific Output Doubles Every Nine Years. 2014; <http://blogs.nature.com/news/2014/05/global-scientific-output-doubles-every-nine-years.html>. Accessed December 31, 2019.

54. Bryant AD, Fletcher GS, Payne TH. Drug interaction alert override rates in the Meaningful Use era: no evidence of progress. *Appl Clin Inform.* 2014;5(3):802-813.PMID: 25298818.DOI: 10.4338/ACI-2013-12-RA-0103

55. Caban J, Gotz D. Visual Analytics in Healthcare--Opportunities and Research Challenges. *J Am Med Inform Assoc.* 2015;22(2):s260-262.PMID: 25814539.DOI: 10.1093/jamia/ocv006

56. Morita PP, Cafazzo JA. Challenges and Paradoxes of Human Factors in Health Technology Design. *JMIR Hum Factors.* 2016;3(1):e11.PMID: 27025862.DOI: 10.2196/humanfactors.4653

57. Carter J. User-Centered Design "Gotchas"— Glad It's Not Just Me. 2016; <https://www.ehrscience.com/2016/03/07/user-centered-design-gotchas-glad-its-not-just-me/>. Accessed December 31, 2019.

58. Keohane CA, Bane AD, Featherstone E, et al. Quantifying nursing workflow in medication administration. *J Nurs Adm.* 2008;38(1):19-26.PMID: 18157001.DOI: 10.1097/01.NNA.0000295628.87968.bc

59. Thomson MS, Gruneir A, Lee M, et al. Nursing time devoted to medication administration in long-term care: clinical, safety, and resource implications. *J Am Geriatr Soc.* 2009;57(2):266-272.PMID: 19170782.DOI: 10.1111/j.1532-5415.2008.02101.x

60. Holden RJ, Rivera-Rodriguez AJ, Faye H, et al. Automation and adaptation: Nurses' problem-solving behavior following the implementation of bar coded medication administration technology. *Cogn Technol Work.* 2013;15(3):283-296.PMID: 24443642.DOI: 10.1007/s10111-012-0229-4

61. Patterson ES, Cook RI, Render ML. Improving patient safety by identifying side effects from introducing bar coding in medication administration. *J Am Med Inform Assoc.* 2002;9(5):540-553.PMID: 12223506.DOI: 10.1197/jamia.m1061

62. Staggers N, Clark L, Blaz JW, Kapsandoy S. Nurses' information management and use of electronic tools during acute care handoffs. *West J Nurs Res.* 2012;34(2):153-173.PMID: 21540355.DOI: 10.1177/0193945911407089

63. Staggers N, Clark L, Blaz JW, Kapsandoy S. Why patient summaries in electronic health records do not provide the cognitive support necessary for nurses’ handoffs on medical and surgical units: insights from interviews and observations. *Health Inform J.* 2011;17(3):209-223.PMID: 21937463.DOI: 10.1177/1460458211405809

64. Drach-Zahavy A, Hadid N. Nursing handovers as resilient points of care: linking handover strategies to treatment errors in the patient care in the following shift. *J Adv Nurs.* 2015;71(5):1135-1145.PMID: 25641374.DOI: 10.1111/jan.12615

65. Braaf S, Manias E, Riley R. The role of documents and documentation in communication failure across the perioperative pathway. A literature review. *Int J Nurs Stud.* 2011;48(8):1024-1038.PMID: 21669433.DOI: 10.1016/j.ijnurstu.2011.05.009

66. Aubry B. CMS and AMA: 2021 proposewd changes to E/M outpatient srevices. 2019; <https://www.3mhisinsideangle.com/blog-post/cms-and-ama-2021-proposed-changes-to-the-evaluation-and-management-e-m-outpatient-services/>. Accessed December 31, 2019.

67. HL7 International. Da Vinci Project: About the Da Vinci Project. n.d.; <http://www.hl7.org/about/davinci/>. Accessed December 31, 2019.

68. Mandel JC, Kreda DA, Mandl KD, et al. SMART on FHIR: a standards-based, interoperable apps platform for electronic health records. *J Am Med Inform Assoc.* 2016;23(5):899-908.PMID: 26911829.DOI: 10.1093/jamia/ocv189

69. Meehan RA, Mon DT, Kelly KM, et al. Increasing EHR system usability through standards: Conformance criteria in the HL7 EHR-system functional model. *J Biomed Inform.* 2016;63:169-173.PMID: 27523469.DOI: 10.1016/j.jbi.2016.08.015

70. HL7 International. Usability. n. d.; <https://wiki.hl7.org/Usability>. Accessed December 31, 2019.

71. Koppel R, Kreda D. Health care information technology vendors' "hold harmless" clause: implications for patients and clinicians. *JAMA.* 2009;301(12):1276-1278.PMID: 19318655.DOI: 10.1001/jama.2009.398

72. Sittig DF, Belmont E, Singh H. Improving the safety of health information technology requires shared responsibility: It is time we all step up. *Healthc (Amst).* 2018;6(1):7-12.PMID: 28716376.DOI: 10.1016/j.hjdsi.2017.06.004

73. Sieja A, Markley K, Pell J, et al. Optimization Sprints: Improving Clinician Satisfaction and Teamwork by Rapidly Reducing Electronic Health Record Burden. *Mayo Clin Proc.* 2019;94(5):793-802.PMID: 30824281.DOI: 10.1016/j.mayocp.2018.08.036

74. American Hospital Association. Well Being Playbook: A Guide for Hospital and Health System Leaders. 2019; <https://www.aha.org/system/files/media/file/2019/05/plf-well-being-playbook.pdf>. Accessed December 31, 2019.

75. Tabarrok A. Are Health Administrators To Blame? 2019; <https://marginalrevolution.com/marginalrevolution/2019/08/are-health-administrators-to-blame.html>. Accessed December 31, 2019.

76. Kocher R. The Downside of Health Care Job Growth. 2013, September 23; <https://hbr.org/2013/09/the-downside-of-health-care-job-growth>. Accessed December 31, 2019.

77. Sorace J, Wong HH, Worrall C, et al. The complexity of disease combinations in the Medicare population. *Popul Health Manag.* 2011;14(4):161-166.PMID: 21241184.DOI: 10.1089/pop.2010.0044

78. Rezaeee ME, LeRoy L, White A, et al. Understanding the High Prevalence of Low-Prevalence Chronic Disease Combinations: Databases and Methods for Research. 2013; <https://aspe.hhs.gov/pdf-report/understanding-high-prevalence-low-prevalence-chronic-disease-combinations-databases-and-methods-research>. Accessed December 31, 2019.

79. Rudin RS, Gidengil CA, Predmore Z, et al. Identifying and Coordinating Care for Complex Patients: Findings from the Leading Edge of Analytics and Health Information Technology. *Rand Health Q.* 2017;6(3):2.PMID: 28845354.

80. Nyweide DJ, Weeks WB, Gottlieb DJ, et al. Relationship of primary care physicians' patient caseload with measurement of quality and cost performance. *JAMA.* 2009;302(22):2444-2450.PMID: 19996399.DOI: 10.1001/jama.2009.1810

81. Hultman G, Marquard J, Arsoniadis E, et al. Usability Testing of Two Ambulatory EHR Navigators. *Appl Clin Inform.* 2016;7(2):502-515.PMID: 27437057.DOI: 10.4338/ACI-2015-10-RA-0129

82. Carter J. Fixing EHR Usability Requires More Than Doubling-Down on Usability Testing and UCD. 2016; <https://www.ehrscience.com/2016/10/31/fixing-ehr-usability-requires-more-than-doubling-down-on-usability-testing-and-ucd/>. Accessed December 31, 2019.

83. Carter J. EHR Design: Unintended Consequences and Irreconcilable Differences. 2017; <https://www.ehrscience.com/2017/03/06/ehr-design-unintended-consequences-and-irreconcilable-differences/>. Accessed December 31, 2019.

84. Bishop RO, Patrick J, Besiso A. Efficiency achievements from a user-developed real-time modifiable clinical information system. *Ann Emerg Med.* 2015;65(2):133-142 e135.PMID: 24997563.DOI: 10.1016/j.annemergmed.2014.05.032

85. Sanborn TA, Tcheng JE, Anderson HV, et al. ACC/AHA/SCAI 2014 health policy statement on structured reporting for the cardiac catheterization laboratory: a report of the American College of Cardiology Clinical Quality Committee. *J Am Coll Cardiol.* 2014;63(23):2591-2623.PMID: 24685667.DOI: 10.1016/j.jacc.2014.03.020

86. Tcheng JE. Using Data To Generate Evidence Which Drives Value. 2019, February 11; <https://365.himss.org/sites/himss365/files/365/handouts/552576986/handout-SC3_FINAL.pdf>. Accessed December 31, 2019.

87. Gellert GA, Ramirez R, Webster SL. The rise of the medical scribe industry: implications for the advancement of electronic health records. *JAMA.* 2015;313(13):1315-1316.PMID: 25504341.DOI: 10.1001/jama.2014.17128

88. Bates DW, Landman AB. Use of Medical Scribes to Reduce Documentation Burden: Are They Where We Need To Go With Clinical Documentation? *JAMA Int Med.* 2018;178(11):1472-1473.PMID: 30242315.DOI: 10.1001/jamainternmed.2018.3945

89. Office of the National Coordinator for Health Information Technology. Certification of Health IT 2015 Edition. 2015; <https://www.healthit.gov/topic/certification-ehrs/2015-edition>. Accessed December 31, 2019.

90. Evans RS. Electronic Health Records: Then, Now, and in the Future. *Yearb Med Inform.* 2016;Suppl 1:S48-61.PMID: 27199197.DOI: 10.15265/IYS-2016-s006

91. Mandl KD, Mandel JC, Kohane IS. Driving Innovation in Health Systems through an Apps-Based Information Economy. *Cell Syst.* 2015;1(1):8-13.PMID: 26339683.DOI: 10.1016/j.cels.2015.05.001

92. HL7 International. Welcome to the Argonaut Project. 2018; <http://argonautwiki.hl7.org/index.php?title=Main_Page>. Accessed December 31, 2019.

93. Osheroff JA, Teich JM, Levick D, et al. *Improving Outcomes with Clinical Decision Support: An Implementer's Guide.* Chicago, IL: CRC Press; 2012.ISBN: 9780984457731

94. Tcheng JE, Bakken S, Bates DW, et al. *Optimizing Strategies for Clinical Decision Support: Summary of a Meeting Series.* Washington, DC: National Academy of Medicine; 2017.ISBN: 9781947103092

95. Weeks J, Pardee R. Learning to Share Health Care Data: A Brief Timeline of Influential Common Data Models and Distributed Health Data Networks in U.S. Health Care Research. *EGEMS (Wash DC).* 2019;7(1):4.PMID: 30937326.DOI: 10.5334/egems.279

96. Senathirajah Y, Bakken S, Kaufman D. The clinician in the Driver's Seat: part 1 - a drag/drop user-composable electronic health record platform. *J Biomed Inform.* 2014;52:165-176.PMID: 25240253.DOI: 10.1016/j.jbi.2014.09.002

97. Carter J. Liberating the EHR User Interface, Part II: Workflows and Widgets. 2015; <https://www.ehrscience.com/2015/10/19/liberating-the-ehr-user-interface-part-ii-workflows-and-widgets/>. Accessed December 31, 2019.

98. Topol E. *Deep Medicine: How Artificial Intelligence Can Make Medicine Human Again.* New York, NY: Basic Books; 2019.ISBN: 9781541644632

99. Lin SY, Shanafelt TD, Asch SM. Reimagining Clinical Documentation With Artificial Intelligence. *Mayo Clin Proc.* 2018;93(5):563-565.PMID: 29631808.DOI: 10.1016/j.mayocp.2018.02.016

100. Mehta N, Devarakonda MV. Machine learning, natural language programming, and electronic health records: The next step in the artificial intelligence journey? *J Allergy Clin Immunol.* 2018;141(6):2019-2021 e2011.PMID: 29518424.DOI: 10.1016/j.jaci.2018.02.025

101. Knight W. MIT Technology Review: The Dark Secret at the Heart of AI. 2017; <https://www.technologyreview.com/s/604087/the-dark-secret-at-the-heart-of-ai/>. Accessed December 31, 2019.

102. Schwartz WB. Medicine and the computer. The promise and problems of change. *N Engl J Med.* 1970;283(23):1257-1264.PMID: 4920342.DOI: 10.1056/NEJM197012032832305

103. Classen DC, Bates DW. Finding the Meaning in Meaningful Use. *New England Journal of Medicine.* 2011;365(9):855-858.PMID: 21879906.DOI: 10.1056/NEJMsb1103659

104. Colicchio TK, Cimino JJ, Del Fiol G. Unintended Consequences of Nationwide Electronic Health Record Adoption: Challenges and Opportunities in the Post-Meaningful Use Era. *J Med Internet Res.* 2019;21(6):e13313.PMID: 31162125.DOI: 10.2196/13313

105. Verghese A, Shah NH, Harrington RA. What This Computer Needs Is a Physician: Humanism and Artificial Intelligence. *JAMA.* 2018;319(1):19-20.PMID: 29261830.DOI: 10.1001/jama.2017.19198

106. National Aeronautics and Space Administration. John F. Kennedy Moon Speech - Rice Stadium. n. d.; <https://er.jsc.nasa.gov/seh/ricetalk.htm>. Accessed December 31, 2019.

107. National Aeronautics and Space Administration. Apollo 11. n. d.; <https://www.nasa.gov/mission_pages/apollo/apollo11.html>. Accessed December 31, 2019.