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Potential Impact of Advanced Clinical Information Technology on Healthcare in 2015

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Abstract

Clinical information technologies now sporadically available will soon be in routine clinical use, bringing many changes to healthcare. For example, 1) The next generation Internet; 2) Real-time clinical decision support systems; 3) Off-line, population-based systems; 4) Large, integrated, individual patient-level phenotypic and genotypic databases with intelligent data mining capabilities; 5) Wireless, invasive and non-invasive physiologic monitoring devices; 6) Natural Language Processing (NLP) systems; and 7) Mathematical models of complex biological systems have the potential to impact significantly the future healthcare delivery system. While new information management and communication techniques and technologies will reduce many of the inefficiencies and inaccuracies of our present systems, there will be an equal, and potentially far more dangerous, set of unintended consequences. Informatics investigators and health system administrators must focus on the study of what is working and what is not, as well as, on development and testing of the new clinical information management and communication technologies, if we are to be ready for the future.

Keywords

Clinical information technology, future, healthcare

Introduction

Neils Bohr, the 1922 Nobel Laureate in Physics said, "The business of predicting is difficult, especially when it's about the future". This manuscript describes how several clinical information management and communication technologies might play out over the coming years. If correctly done, such predictions can help individuals and their organizations prepare for changes. In addition, such predictions should help researchers focus their efforts on attempting to address the myriad challenges that must be overcome before any of these ideas can reach fruition. In contrast to Haux et al. [1], who provide specific estimates of the size of the change expected by the year 2013 without regard for how these changes may occur, I have attempted to describe a few key clinical information management and communication concepts and how they might effect the healthcare environment in the future. My basic belief is that several clinical information technologies now available in experimental and pilot form will be in routine clinical use within the next 12 years, bringing many changes to the healthcare environment. For as William Gibson noted, "The future is here now, it's just unevenly distributed".

Adoption of Technology in Healthcare

It took the Internet, one of the fastest growing information technologies ever, almost 30 years to be widely adopted in the United States, and the majority of the world's population is still relatively unaffected by it [2]. Witness the extremely slow uptake of clinicians' use of email with their patients due to numerous real and perceived barriers [3]. In addition, even though Computer-based Physician Order Entry (CPOE) has been available for over 25 years yet there are still only a small minority of clinicians actually using such systems [4,5].

Potential users of new technology should not wait for others to create and perfect new tools but plunge ahead and begin exploring their uses themselves. For as Dr. Alan Kay said, "The best way to predict the future is to invent it!"[1*]

The following section describes one aspect of the future healthcare environment. This section is followed by descriptions of some key clinical information management and communications concepts and their potential impact on the coming healthcare environment.

The Healthcare Environment in 2015

If present trends continue, by the year 2015 over 35% of the adult population in the United States will be obese (BMI $\geq$ 30) [6]. Similarly, the percentage of people over the age of 65 will increase by 35% [7]. Given that the overweight and the elderly account for a significantly higher percentage of all healthcare utilization, by the year 2015, we can expect a significant increase in the overall demand for healthcare services. Therefore, without several significant new developments in information management technologies the healthcare system as we know it will cease to function.

Key Clinical Information Management and Communications Concepts

Next Generation Internet and Wireless Handheld Devices

The next generation Internet [8, 9] with its higher speed will allow patients and clinicians to access a worldwide network of specialized clinical experts in either a synchronous or asynchronous manner. This technology will greatly reduce and eventually eliminate the current time and distance restrictions on access to the best clinical providers. Such a system will allow a relatively

1. * Uttered by Dr. Alan Kay in a fit of passion at a meeting with Xerox planners at the *Palo Alto Research Center* in 1971.

small group of specialists to treat a large percentage of all patients with a particular condition in an efficient and effective manner. Many of these clinicians will be "on-call" using the next generation of internet-accessible, wireless handheld computing and communication devices. The current generation of cell phones provides Internet access coupled with the ability to send still pictures and stores relatively small amounts of information. Future generations of these small devices will enable clinicians to participate in high-quality, full motion videoconferences while simultaneously accessing the patient's complete electronic medical record along with the most advanced, real-time, clinical decision support capabilities.

The first applications of this type of technology will likely be in radiology [10] or dermatology since much of their work is already done in isolated rooms using high-quality digital images; thus the ability to easily move these images around the globe quickly and securely will make local, on-call experts dispensable. Clinicians could also use this technology to ask colleagues for a simple review of a patient's chart rather than a full, in-person referral visit, saving both the patient's and the clinician's time.

Clinical Decision Support Systems

Real-time, Point of Care Systems

Continued improvements in real-time clinical decision support systems will allow experienced clinicians with less formal academic training than current primary care physicians to diagnose and treat a wide range of patients safely, efficiently, and effectively [11]. This dramatic change in the "scope of practice" will significantly reduce the cost of healthcare and increase the access of acutely ill patients to expert help by freeing up the most highly trained clinicians to handle the complex, time-sensitive cases.

The first applications of this type of technology will likely be extensions to existing computer-based clinical practice guideline systems that help guide current clinicians through difficult patient management situations. Such systems are already in use for selected patients in many institutions with advanced clinical information systems [12].

Off-line, Population-based Systems

Off-line, population-based systems utilizing complex clinical rule sets will identify groups of patients eligible for large randomized controlled clinical trials and those in need of particular clinical treatments or preventive screening procedures [13], which will greatly improve compliance with evidence-based clinical guidelines. Once the patients are identified, these systems can be programmed to reach out automatically by interactive voice response messaging systems or email to remind them to take their medicine or schedule an appointment for appropriate testing or care.

For example in a recent study, Israeli researchers developed a system that ran nightly checking that all patients who purchased diuretics from the pharmacy had a recent potassium blood test [14]. For those patients without a recent test, they send a computer-generated reminder to their physician. These reminders increased potassium testing by 9.8%. ($p<0.001$). Following this successful test, they are now planning on sending alerts directly to patients.

Large, Integrated Clinical (Phenotypic) and Genotypic Databases with Intelligent Data Mining Capabilities

Large, regionally, nationally, or internationally integrated, individual patient-level phenotypic and genotypic databases with intelligent data mining capabilities will allow clinicians to identify best practices and then optimize and individualize diagnostic and therapeutic regimens [15]. The current state-of-the-art clinical information systems deliver so-called patient-specific clinical recommendations at the point of care, but these recommendations do not routinely take into account the patient's genomic information. With the continued development of a) our understanding of the meaning of genetic information and b) our ability to rapidly and accurately collect and securely store this individual-level information, clinicians will soon be able to develop truly patient-specific clinical diagnostic and therapeutic regimens.

For example, Japanese investigators have conducted several large-scale research projects and have identified 6 genes associated with type 2 diabetes mellitus [16]. In a separate effort to gain further knowledge about rare genetic diseases, German researchers have developed an internet-accessible, data collection system [17]. Using this system they have collected case reports from at least 295 patients with rare genetic disorders. Their database includes over 1500 clinical symptoms and over 5000 laboratory findings. Using this database they hope to be able to identify phenotype-genotype correlations.

Wireless, Invasive and Non-invasive Physiologic Monitoring Devices

Wireless, invasive and non-invasive physiologic monitoring devices will enable the chronically ill and the elderly to live on their own, yet be closely monitored by artificially intelligent computer systems that alert clinicians to patients' needs [18]. Such systems will significantly increase the demand for healthcare systems to have clinical care managers and home healthcare workers continuously available to respond to crisis situations.

Studies are already underway to test systems that are capable of the automatic acquisition of blood pressure, cardiac output and other hemodynamic parameters on a beat-by-beat basis using the volume-compensation and transthoracic electrical impedance method [19]. Investigators have also developed home monitoring systems that can be installed in a lavatory to measure body and excreta weight without attachment of sensors to the person and without special operations for measurement during toilet use.

Natural Language Processing Systems

Natural Language Processing (NLP) Systems capable of turning freetext documents into coded clinical findings will enable clinicians to enter their notes and orders into the computer via automatic speech recognition interfaces or by free form typing. These NLP systems will allow future clinical information systems to capture an unprecedented level of coded, patient-specific clinical information. Using this coded information in conjunction with advanced, artificially intelligent systems capable of interpreting and summarizing it will enable these systems to provide an unparalleled level of clinical decision support [20, 21].

For example, Bates et al. reviewed 25 studies that reported on the use of natural language processing tools to detect certain types of adverse events from free text clinical databases [22]. They found that these approaches already work well for the detection of nosocomial infections, adverse drug events, and falls. They concluded that these NLP systems are already more accurate than spontaneous reporting by clinical personnel and more timely and cost-effective than manual chart reviews.

Mathematical models of complex biological systems

Increases in our understanding of complex biological processes coupled with extraordinary access to the vast computational power represented by the machines attached to the Internet [23] will give rise to mathematical models of biological systems that will enable researchers to make predictions about physiologic phenomena with great accuracy [24]. Such models and their resulting predictions will allow clinicians to prioritize each patient's therapy so as to maximize life expectancy while minimizing out-of-pocket expenses and risks of adverse side-effects from unwarranted pharmaceutical therapies. These models would also allow health care administrators or public health policy makers to simulate the effect of various clinical guidelines on the health of the entire patient population, taking into account such variables as the availability of health care facilities, costs, and utilization of clinical resources.

Unintended Consequences of the New Technologies will Abound

While new information management techniques and technologies will reduce many of the inefficiencies and inaccuracies of our present healthcare delivery system [25], there will be an equal, and potentially far more dangerous, set of unintended consequences [26]. Prediction of these unintended consequences is even more difficult than the prediction of the potential impact of future technology developments. Our past experience has taught us that unintended consequences will occur and health care organizations must be prepared to capitalize on the positive consequences and respond to the problems. For example, one of the predicted benefits of currently available clinical information systems was to reduce the amount of paper used [27]. In fact the implementation of these systems has only served to multiply the amount of paper used. Another proposed benefit of computer-based physician order entry systems was to be an improvement in speed and accuracy of communication among members of the same healthcare team. Unfortunately, the capability of entering orders from anywhere within the hospital (or even from home) that is often identified by physicians as one of the best aspects of these new systems [28] has greatly decreased the amount of communication between physicians and caregivers on the hospital wards [29] increasing the overall potential for misunderstandings [30].

Key Lessons Learned

Several of the lessons developers of clinical information systems have learned over the past 30 years could be helpful to those setting out to test and implement new concepts. For example, each employee must clearly understand the benefits of new technologies or the rate of their diffusion across the organization will be very slow [31]. Healthcare workers must realize that the organization will gain financially, in service quality, or in safety, preferably all three, or acceptance of new ideas will be minimal. The limited use of computerized patient records (CPRs) throughout health care systems after 30 years of effort is one clear example. In addition, we have learned that without organizational leadership any new approach is likely to fail. The new technology must fit into the existing clinical workflow or it will be ignored. The life and death situations existing in healthcare require that any new machine or method be fast and reliable [32].

Conclusions

Prototypes or pilot implementations of most of these concepts are available in a few state-of-the-art healthcare facilities around the world today. Many of these changes will deliver clear improvements in patient care and provider and organizational welfare, while others will lead to severe unintended consequences. Keeping in mind likely future increases in healthcare demands, the lessons learned to date, and watching for unexpected consequences of the new technologies, informatics investigators and health system administrators must continue to study what is currently working and what is not, as well as, on development and testing of the next generation clinical information management and communication technologies, if we are to be ready for the future.

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