The Impact of Direct Data Entry by Sensory Devices on EMR Systems

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Abstract. This paper takes an interdisciplinary look at how the electronic record is likely to evolve in the future. From what new sources will data be drawn? Will such data be directly recorded from sensory devices and from one's personal "memex"? Will these data enable a new set of outputs to more fully interconnect patients with their health care system. The paper considers the combined impact of a host of emerging technologies:

1. the impact of the networking phenomenon
2. the impact of adding robust patient access to the EMR
3. the impact of the growing emergence of PHRs
4. the impact of emerging technologies on the usability of the EMR
5. the impact of direct sensory input devices
6. the impact of bioinformatics and genomics
7. the impact of the personal memex

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1 Introduction

The EMR is very much a system in development. After a struggle of about 50 years[1], the notion of an Electronic Medical Record [EMR] has now finally begun to take firm root in the USA and elsewhere. Spurred by encouragement from the American government as a way to reduce medical errors[2] and to stem the inherent inefficiency of the paper-based record, most major healthcare institutions in the USA now have emerging EMR projects in various stage of implementation[3] .

[1] The first attempt at creating an electronic medical record may have occurred at Kaiser-Permanente circa 1956 [1].

[2] Perhaps the most dramatic moment occurred in the year 2000 when the Institute of Medicine published its now classic paper "To Err is Human" in which it postulated that perhaps as many as 98,000 lives are lost each year due to medical error in the United States [2].

[3] It is estimated that approximately 8% of health information is currently collected using EMR technology in the USA [3].

D.D. Schmorrow, L.M. Reeves (Eds.): Augmented Cognition, HCII 2007, LNAI 4565, pp. 57–64, 2007.

It is clear that the "electronification" of health datawill have impacts far beyond those of the immediate use of the data in direct clinical care. For the first time in human history, detailed patient-identified data will be digitally created on a massive scale. This availability will reduce the need for timely and costly chart audits which introduce significant error and bias into data analysis.

How will this massive amount of data be collected? Clearly the great bulk of this data will need to be entered from electronic sources. On a relatively small scale data from interfaced clinical laboratory equipment is already collected in this way. Is it, in addition, possible that in the not-so-distant future patient-specific data might flow directly to the EMR via sensory devices, and that one's genomic data might also directly populate one's EMR?

In this paper, we attempt to look at the future implications of the Electronic Medical Record – how it will likely evolve, how data is likely to be collected, the purposes to which the data will be put, and how a host of new emerging technologies may impact that progression.

2 The Impact of the Network Phenomenon

Like the progression of the personal computer itself, great synergy is created by linking stand-alone sites together in a network configuration. In the USA, the recent interest in the creation of RHIOs (Regional Health Information Organizations) has had some success in inter-linking EMRs at different institutions within a larger catchment area[4].

However, as with the RHIOs' predecessor, the CHINs[5] (Community Health Information Networks), the exact use and utility of this interlinking is still not clear.

The first use of the RHIO will likely be to improve the flow of "upward referrals" from lower levels of care (especially primary care) to tertiary hospitals and academic medical centers. This improvement will address many of the issues relating to the current paucity of data which is currently available to a receiving emergency room or super-specialist clinic.

After "upward referrals" are addressed, it is likely that we will finally begin to address a perhaps even more significant and vexing problem, that of "downward referrals", i.e. how to move the patient, along with his or her newly generated clinical information, back down to a more appropriate (and more cost-effective) level of care once the specialty treatment episode has concluded [6]. This return to lower-levels of care has been hampered by a litany of perverse economic, regulatory and social incentives which generally prize "holding on to a patient" as long as possible. Whether specialists can be cajoled into loosening up on this social grip remains to be seen.

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[4] In Hawaii, for example, the Holomua Project [4] is underway to link 5 public Primary Care Clinics with 2 large tertiary urban health centers on the island of O`ahu.

[5] Most of the CHINs of the 1980's failed miserably to garner the support needed from the various competing stakeholders.

[6] In Hawaii it is estimated that only 30% of patients suffering their first Myocardial Infarction are adequately returned to primary care for long-term management of their Coronary Artery Disease [5].

After referrals, and authorizations for referrals, are fully automated, we may have the luxury of considering an even more dramatic change – can the electronic availability of patient data (via the EMR) actually allow full and virtual collaboration on treatment among institutions in a community? With an MRI done in one institution, a super-specialist in another, and post-intervention therapies in yet another, could we remake our healthcare institutions to be less duplicative (read, requiring less capital expenditure) and more complementary and collaborative?[7]

Could, further, the emergence of the EMR be one of the missing pieces which finally makes telemedicine available on a broad scale? Telemedicine is yet another high-technology initiative which has engendered speculation since 1924[8] (!), but has languished largely because of the lack of "glue" to bind healthcare institutions together.[9]

The convergence of the EMR and initiatives in telemedicine may cause a major realignment and rethinking of the fundamental way that healthcare is provided across the continuum of care. In these new circumstances important issues of security, confidentiality, privacy and access rights will have to be addressed. In this larger environment, these issues will dwarf those we face today as more and more institutions have some access to medical histories.

3 The Impact of Adding Robust Patient Access to the EMR

Given the general spread of computers and availability of broadband connections, people have become familiar with secure access via the web to their personal data, such as to their bank accounts, share holdings, etc. There appears to be no good reason why they should not also have access to the bulk of their medical and

[7] We stress again the need to look at the vexing fragmentation problem in the context of a plethora of economic, legal, regulatory and social complexities.

[8]

Radio News magazine, April 1924

[9] It can be reasonably argued that there are of course other pernicious reasons why the scope of telemedical practice has remained so limited relative to its long-touted potential. Among these in America are the statutory restriction of medical practice across state lines, perverse or non-existent economic incentives, and the general sense that telemedicine is often inconvenient and poorly orchestrated.

pharmaceutical records. As reported in [6] this facility is already under development in various forms at several sites in the US, such as at Kaiser-Permanente, the Group Health Cooperative in Seattle, Beth Israel Deaconess Medical Center in Boston, and the Cleveland Clinic. The various online services offered (by at least one of these institutions) include allowing patients to:

(a) View their own medical records, including lab. results, radiology reports, allergy results, with links to lay person explanations of procedures and tests (Physician office notes are however not included.)
(b) Make appointments
(c) Request referrals
(d) Post questions. Triage nurses are employed to answer these, making use of a library of customizable prewritten templates. Questions are forwarded on to physicians only where necessary
(e) Populate the database with their own family and social histories.

In addition to the explanation of diagnostic test results and optional therapies referred to in (a), broadband connection makes possible the explanation of medical conditions with graphics and video components. Furthermore, the emerging technologies of natural language processing and web searching will increase the potential of systems implementing computer-generated responses, and so relieve some of the burden and cost of answering patient in queries (see d). Just how far and how fast patients will be given such robust access to their medical information remains an open question.

4 The Impact of the Growing Emergence of PHRs

Patients will not only want/demand robust access to their EMRs, but will also want to make entries about their own personal health data. Already a large number of products have been developed (as listed e.g. in [7]) to attempt to assist users in the creation and maintenance of their own PHRs (Personal Health Reports). These PHRs are intended to serve as central depositories of data that may be spread over the medical records maintained by numerous health-care providers, and serve such functions as avoiding duplicate tests, and providing new physicians with additional medical history.

The fact of the matter is that, at least in the USA, there exists no ideal place to house one's (truly longitudinal) clinical data. The very nature of the fragmented healthcare system (or putting it more kindly of our independent mostly laisser-faire system) assures that no one point is ideal. In the USA, therefore, we will likely see the continued growth of institutionally owned EMRs (whose focus, logically enough, is to benefit that institution). Thus PHRs will continue to be attractive.

Patients can add to their PHRs information that would not otherwise be collected, e.g. their use of over-the-counter [OTC] medication, drug interactions, vital signs, nutritional data, signs and symptoms, etc.

There is clearly a close relationship between the EMR and the PHR. Patients will obviously want the ability to download material from their EMRs to their PHRs, and have links to their PHRs inserted into their EMRs. Will facilities for such cross-

references indeed be incorporated into the EMR? If so, a number of important questions need to be addressed, including: (a) patients may not have enough medical knowledge to know what to put into their PHRs (b) most importantly, can a physician legally and reasonably act on information placed in the PHR by a patient without validating it?

For these reasons and more, the PHR has had a limited penetration into the "mainstream" of medical care. Certain hybrids have emerged which combine certain aspects of EMR and PHR[10]. These hybrids have thus far been less than satisfactory.

5 The Impact of Emerging Technologies on the Usability of the EMR

In addition to new data entry methods, new search techniques, and new paradigms of patient involvement, we will need to fundamentally assess the usability of our current practices. Might new technologies help in this regard?

Busy doctors and nurses resist having to resort to data access terminals in order to input or extract information. The integration of EMR with Wi-Fi mobile devices can go a long way to solving this problem. The technology for this is beginning to make an appearance [8] . Examples of such devices include:

a) *Pda's and tablet computers.* A number of hospitals, such as the Ohio State University Medical Center (OSU), have established access points through out their hospital for this purpose.
b) *Wireless wearable computers with LCD screen mounted glasses.* Devices of this kind go one step further than pda's as far as convenience is concerned. The cost and weight problems which have hindered their acceptance are being solved as a side-effect of Moore's law on the doubling of computer speed for a given cost. Some doctors at OSU have already begun wearing devices of this kind.
c) *Voice recognition* which can add a significant convenience factor for many input chores. The technology involved is improving. It is one of those technologies which benefits from increased raw computer power[11]. Radiology transcription systems, for instance, are now quite good, given that they use a relatively small specialized vocabulary, but they still suffer from occasional almost comical blunders. A much larger vocabulary will be required for robust diverse description in Internal Medicine, which is now beyond the reach of today's computing power, but this limitation will likely gradually fade over time.
d) *Hand-held scanners*. We are all familiar with the use of these devices by car-rental companies and your friendly Fedex delivery man, and they have begun to find their way into hospitals. Such scanners can also be put to use on a large scale to keep track of medication dispensed to patients. For instance on administering medication to a patient, the nurse involved scans the bar codes on

[10] Experiments at Kaiser-Permanente, Oakland, for example have given the patient "views" of her clinical data and limited ability to add "patient-entered" data, but these data are not fully integrated with "institution-entered" data.
[11] For instance the recent introduction of multi-core processors will have an immediate impact on the capability of voice recognition systems.

the medication, the patient's wristband and her own badge. Together with the timestamp, the information can immediately be posted to the Medication Administration Record (MAR).

The full adoption of these devices might spur further progress in data collection. Of course with this opportunity comes the now familiar battle between confidentiality and accessibility. In order to be HIPAA-compliant[12], robust encryption and authentication protocols need to be employed, e.g. using WEP or other encryption schemes (as well as the usual security needs such as user id's, passwords, etc). Other important problems that require attention include network reliability (particularly critical in this case), access point placement, and (today's relatively short) battery lives. Finally, interference can be caused by radio devices inside a medical institution which can potentially have dangerous effects on telemetry, and even on patient-imbedded devices such as pacemakers.

6 The Impact of Direct Sensory Input Devices

If one accepts the premise that the world (and the "healthcare world" specifically) will soon be highly interconnected, that patient's will have/demand robust access to that world, and that in fact the PHR might become an umbrella under which the fragmented data at the healthcare institutions is stored, then we are led to the question about how such data will be entered.

EMR systems may evolve from one in which all entries are made by human users (be it the health institution, the clinician or the patient), into a system which also receives some direct input from sensory devices in the environment, and ones attached to patients using nanotechnologies and other relatively noninvasive methods. A large multi-country project called MobiHealth [9] has been funded by the European Commission to develop a system employing such devices.

Although sensory acquisition has been with us for decades (an early example being the Holter Monitor used to monitor irregular heart rhythms of known cardiac patients), the full potential of our ability to harness real-time acquisition of health data has really not yet been explored in the mainstream of medicine.

An example where an EMR system would benefit from data acquired in this way is supplied in [10]. This report describes a tiny wireless device which can be implanted in a tumor to tell doctors the precise location of the cancer and the exact amount of radiation it's receiving. A study of such data obtained from patient EMRs around the country, with information about the outcomes, would be of significant use in determining optimum therapy for such cases.

Clearly direct input from sensory devices provides us with a host of technical, social and legal challenges if it were to be adopted on a routine basis. The potential benefits are great however, especially in a world fraught with the scourge of an ever-increasing burden of cardiac disease and Diabetes Mellitus, to name just two of the diseases that could potentially be monitored in a connected world.

[12] USA: The Health Insurance Portability and Accountability Act of 1996.

7 The Impact of Bioinformatics and Genomics

Another future source of massive amounts of data to be collected and managed by the EMR will result from the appearance and availability of bioinformatic and genomic data.

Abnormalities related to over 1,600 genes have been linked to specific health conditions, and this number is rapidly growing with continued research [11] . About 2/3 of these genes are available for specific genetic tests ordered by physicians. Examples of such health conditions include:

(a) increased risks of multiple forms of cancer, with a consequent need for continual surveillance
(b) abnormally increased or decreased ability to metabolize certain drugs, with a consequent need for doses prescribed by physicians to be adjusted accordingly
(c) susceptibility to permanent hearing loss if certain drugs are taken
(d) susceptibility of infants to mental retardation on ingesting phenylalanine, an essential component of most sources of protein.

There is an obvious need for physicians to keep track of such factors, but the large number of known effects, and the rapidity with which others are being discovered, makes this extremely difficult. As [11] argues, EMR systems need to be altered to include a standard format for information obtained about a patient's genome. The entry of such information should elicit warnings about associated health conditions applicable to that specific patient. Furthermore, as new links between genes and health conditions are discovered, warnings should be sent out to the physician and/or the patient using a centralized computer system that identifies the patients concerned by accessing the genomic information in patient's records across the country [13]. Genes related to a disease often only increase the probability that the patient involved will suffer from it, but patients may misinterpret the advisory and think that it indicates that they actually already have the disease. Accordingly the data selected to be presented to patients should be accompanied where necessary with an interpretation of the possible impact and probabilities of progression, with references to the germane literature.

8 The Impact of the Personal Memex

A more speculative extension to the discussion about future sources of health data comes from Jim Gray's 1998 Turing Award Speech [12], in which he argued that, with Moore's Law, we will soon achieve the capability of creating what he calls a "Personal Memex". This is a system for recording everything one saw, read, or heard. Might there be benefits to linking the Personal Memexs of patients to an EMR system, such as for investigating the origin of health problems, and for extensions of, and additions to, the applications of sensory data input described above? What analysis and search tools would be needed to deal with such a large and complex data

[13] We fully acknowledge the huge cultural barriers which present themselves here. The idea of a "central computer system" which tracks everybody's genomic data raises major issues revolving around patient confidentiality and data security. Can they be overcome? This remains to be seen.

structure? One can only imagine the possibilities and the richness of new knowledge which could result[14].

9 Conclusion

We remain at present at the very infancy of understanding the true nature of the EMR. While today's efforts are largely focused on minimizing the fragmentation of medical information for direct patient care within one institution or healthcare organization, the potential sources of inputs into the EMR,, and the potential outputs of the EMR clearly goes far beyond the realm of the doctor's office or hospital bed.

One thing is clear, the full emergence of the EMR will impact our healthcare delivery system at many levels; the secondary and tertiary effects may be even more profound than the impact on direct patient care itself.

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[14] Even if the Personal Memex were never to come into ubiquitous use, it is possible that extensive diverse information about individuals will come to be collected, or linked together, in some standard format. In addition to EMRs, this could include such information as additional personal data, academic credentials, personal blogs, bank accounts, and perhaps credit reports, criminal histories, etc. Issues of security, confidentiality, privacy, and access rights will have to be addressed here not only with respect to EMRs, but also to these other categories of data.

[15] All the URLs listed here were last revisited on 2/14/2007.