Closing the Loop between Clinical Practice, Research, and Education: The Potential of Electronic Patient Records

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Summary
Objective: To discuss the possible contribution of electronic patient records in closing the loop among clinical practice, research and education.

Results and conclusions: Applying Information and Communication Technology (ICT) to a given medical domain is not merely adding a new technique. When introduced into an environment, ICT will initially often emulate or resemble the already existing processes. When workers and researchers in that domain begin to appreciate the potential of ICT, this initial stage is followed by more fundamental changes in that domain that take advantage of the potential of ICT. To understand the scope of the potential changes enabled by electronic records, three principle changes need to be understood. First, data recorded in computer memories can be readily retrieved and re-used for a variety of purposes. Second, once data are available in computer memories, the data can be transported easily. Third, as physicians (and patients) are using computers to record medical data, the same electronic record can be used to introduce other computer programs that interact with the user: New usage of data, however, generates additional requirements. Thus the experience in developing decision support systems and analyzing observational databases feeds back into the requirements for electronic medical records. Each patient-physician encounter, each investigation, each laboratory test, and each treatment in medical practice constitutes, in principle, an experiment. Ideally, we learn from each experiment. Electronic medical records will facilitate research that relies on data recorded in routine medical practice. The potential and challenge, however, of Medical Informatics lies in its ability to close the loop among clinical practice, research, and education.

Keywords
Medical record systems, computerized automatic data processing, computer assisted decision making databases, medical informatics

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1. Introduction

The term Medical Informatics dates from the second half of the 1970s and is based on the French term informatique medicaie. Although the term medical informatics is now widely used, other names such as medical computer science, medical information sciences, or computers in medicine are sometimes used. Research in informatics ranges from fundamental computer science to applied informatics. Several definitions of Medical Informatics take both the scientific, fundamental aspect and the applied, pragmatic aspect into account. Shortliffe, for example, provides the following definition:

“Medical Information Science is the science of using system-analytic tools...to develop procedures (algorithms) for management, process control, decision-making and scientific analysis of medical knowledge [1].”

and van Emmel defines the field as:

“Medical Informatics comprises the theoretical and practical aspects of information processing and communication, based on knowledge and experience derived from processes in medicine and health care [1].”

Medical Informatics is determined by the intersection of the terms medicine and informatics. Medicine identifies the area of research. Informatics identifies the methodology used. In Medical Informatics, we develop and assess methods and systems for the acquisition, processing, and interpretation of patient data. Computers are the vehicles to realize these goals. The role of computers in Medical Informatics, however, varies. If the Medical Informatics research is applied, the objective is to develop a computer system that will be used by health-care professionals; for example, research aimed at the development of electronic medical records. If the Medical Informatics research is more fundamental, the computer plays a role as experimental environment for models that are developed; the objective is not to build a system, but to verify a hypothesis or to investigate the limitations of models. Some research in the area of artificial intelligence in medicine, for example, fits this last category.

Applying Information and Communication Technology (ICT) to a given medical domain is not merely adding a new technique. When applied to a medical domain, ICT has the potential to radically change processes in that domain. That change, however, may not be apparent at the beginning. When introduced into an environment, ICT will initially often emulate or resemble the already existing processes. Typically, this is only a temporary stage. When workers and researchers in that domain begin to appreciate the potential of ICT, this initial stage is followed by more fundamental changes in that domain that take advantage of the potential of ICT.

Electronic communication, for example, is a relatively simple technology. The contents of a message may be structured (that is, contain a predefined set of data) or free text. When introduced in the health-care process, electronic communication is used to replace existing paper documents. The
names of the first electronic messages often even carry the names of their paper counterpart: electronic discharge letter, electronic prescription, etc. At first glance, little has changed when compared to the previous paper-based communication except the speed of delivery. In this stage, the infrastructure (e.g., computers, lines) required for ICT has been installed, but the impact of ICT on the processes is still very limited. Subsequently, however, the ability to send data using electronic communication is used to support new forms of collaboration between health-care professionals. At present, the emphasis has shifted from replacing paper documents to sharing data between healthcare professionals. A’s physicians increasingly share data, issues, such as the standardization of the content of medical records, are becoming important areas of research. In addition, the fact that data can be transferred easily over distances enables physicians to interpret data while the patient is located miles away (resulting in, for example, the so-called “tele-diagnosis”) or to communicate with patients over longer distances using, for example, the internet.

Many researchers argue that the fundamental enabling technology is the introduction of electronic medical records. In this paper we will use the electronic patient record as an example. We will first discuss the developments with respect to electronic medical records.

2. Electronic Medical Records

In its early stages, the written medical record had the purpose of documenting the care given to a patient, and thus to facilitate continuity of that care. The entries in the medical record enabled the physician to recall previous episodes of illness and treatment. In recent years, however, medical records have been used increasingly for other purposes; the records are used as a data source for purposes ranging from billing the patient to performing epidemiological studies, and from performing quality control to defending oneself against legal claims. One of the major barriers for using the data in paper medical records for purposes other than providing medical care to an individual patient is the inaccessible and often unstructured nature of the paper medical record. The introduction of computer-based medical records removes, to a large degree, that barrier.

The last decades have seen a rapid increase in the role of computers in medical record keeping, and professional organizations have started to play an active role in the introduction of electronic records. For example, in 1978, the first Dutch general practitioners started using personal computers in their practice. Five years later, in 1983, 35 general practitioners (that is, 0.6 percent of all Dutch general practitioners) were using a computer. In 1990, 35 percent of the Dutch general practitioners were using one or more computer applications; although the majority of these applications are administrative, an increasing number of physicians use computer-stored medical records [3]. At present, the electronic medical record has replaced paper records as the dominant form of records in Dutch primary care. Other countries, e.g., the United Kingdom, have also witnessed a rapid introduction of electronic records in primary care. In secondary care, although progress has been made, the introduction of electronic records is slower.

The explicit purpose of automating medical records is to use the data in those records to support not only care of individual patients, but also applications such as decision support, quality control, cost control, or epidemiology [2]. The quality of medical-record data, however, has often been lamented. The reliability of clinical data, for example, has long been questioned, and tensions between reimbursement schemes and coding schemes have been discussed. Some researchers argue that the process of automation may further reduce the reliability of data. Burnum [4], for example, states: “with the advent of the information era in medicine, we are pouring out a torrent of medical record misinformation.” Athough we disagree with this pessimistic viewpoint, we acknowledge that medical data are recorded for a specific purpose and that this purpose has an influence on what data are recorded and how they are recorded. In developing systems that record medical data, designers of systems make decisions about how to model those data in order to perform a given task. For example, in designing the computer-based medical-record system Elias [3], the designers focused on issues such as ease of data entry and emulating existing paper records. The same designers subsequently discovered significant limitations in the Elias records when they developed a decision-support system that uses these records as a source of data [5].

Despite the limitations of the current computer-based medical records and the data contained in these records, many researchers believe electronic medical records will significantly change medical practice [2, 6]. To understand the scope of the potential changes enabled by electronic records, three principle changes need to be understood. First, data recorded in computer memories can be readily retrieved and re-used for a variety of purposes. A’s result, databases containing data on millions of patients are available. Athough the subsequent analysis of the data may prove difficult, both clinicians and researchers are moving for a period of “data starvation” to “data overload”. Second, once data are available in computer memories, the data can be transported easily. The result is that processes that interpret the data (e.g., diagnosis or consultation) are no longer closely associated with the physical location where the data were collected. Data can be collected in one place and processed in another (for example, tele-diagnosis). Third, as physicians (and patients) are using computers to record medical data, the same electronic record can be used to introduce other computer programs that interact with the user. Electronic medical records require both an extensive ICT infrastructure and clinicians experienced in using that infrastructure. Once that infrastructure is operational, other applications (e.g., decision support or access to literature) are much easier to introduce.

Electronic medical records will stimulate and enable other developments. We will discuss two of these developments: the development and use of integrated decision support systems, and the creation of observational databases.
Clinical decision-support systems require patient data. Without patient data, patient-specific advice cannot be generated. Some systems may require interaction between the system and the clinician. The clinician initiates a dialogue with the system and provides data to the system by entering symptoms or answering questions. Experience with this type of system has shown that the acceptance of this type of system by clinicians is relatively low. Other systems are integrated with electronic medical records, and use the data in these records as input. In such settings, receiving decision support requires little or no additional data input on the part of the clinician. Finally, some systems are directly connected to the devices that generate the data, for example, systems that interpret ECGs or laboratory data.

By applying the medical knowledge to the patient data, the system generates patient-specific advice. Some systems, especially systems integrated with electronic medical records, provide advice independent of a physician's request for advice—unsolicited advice. Examples are reminding systems that continuously screen patient data for conditions that should be brought to the clinician's attention (e.g., the patient's kidney function is decreasing, or the patient is eligible for preventive screening). Other systems, such as critiquing systems, may monitor the decisions of the clinician and report deviations from guidelines.

In the absence of a clear study design (e.g., a randomized controlled trial to compare the effectiveness of possible treatment regimens) and specification of data required for that study, the data in observational databases are difficult to interpret due to possible confounding. The advantage of observational databases, however, is that they reflect current clinical practice. Moreover, the data are readily available, and the costs are not prohibitive. In settings where all the medical data are recorded in an electronic format, the opportunities for research are similar to studies carried out using paper charts. Compared to paper charts, these observational data bases provide an environment where the analysis can be performed quicker, the data are legible, "normal" practice can be studied, rare events can be studied, and the data are readily available.

Observational databases that rely on electronic records have limitations. Analysis of the contents of the records shows that information important for a researcher is often not recorded. Medical records typically contain data describing the patient's state (e.g., the results of laboratory tests), and the actions of the physician (e.g., prescribing medication). Relationships between data are often not recorded. The medical record mainly reflects what is done rather than why. A further complicating factor is that when data in the medical record describes the relationship between observations (or findings) and actions (e.g., treatment), the information is often recorded in the form of free text. The physician's first and most important objective is keeping automated medical records is to document with the purpose of ensuring the quality and availability of medical care. From the physician's perspective, free text is often an ideal method for expressing the patient's condition. Researchers, on the other hand, prefer coded data to facilitate the automatic processing of large numbers
of patients. It is unrealistic, however, to expect physicians to code all relevant data; the time required to code medical data renders it impractical. In addition, coding is in essence a process of reducing the rich presentation of the patient-physician encounter to a limited set of predefined terms. The available data in an observational database may therefore not be sufficient to validly answer a specific research question. The completeness of data can only be discussed in the context of a specific study. It is not possible to predict all possible data that would be required for all possible studies. As a result, data in observational databases will be incomplete. Depending on the study question and the impact of incomplete information, additional data may need to be collected.

5. Closing the Loop

One of the fundamental changes when conventional paper-based medical records are replaced with computer-based records involves the ability to process the data in that record for different purposes. As a result, data in observational databases will be incomplete. Depending on the study question and the impact of incomplete information, additional data may need to be collected.

In the area of decision-support systems, researchers are combining reminder systems that rely solely on already recorded data in the electronic record with systems that request additional information from clinicians. The resulting systems rely on one hand on data already available in the electronic record to determine eligible patients, and subsequently interact with the clinician to assess, for example, whether the patient should be treated according to a certain protocol. The results of that interaction are recorded in the medical record. Researchers working on the development of observational databases are beginning to combine retrospective research with prospective research. Trials are translated into software, distributed electronically, and added to an electronic medical record. Based on data in an electronic medical record, the system automatically detects patients eligible for a trial. The electronic medical record informs the clinician that the patient is eligible, and request permission to include the patient in the trial. The system subsequently performs the randomization between treatment arms during patient consultation, and the electronic record supports subsequent data collection. As a result, the boundaries between an electronic record, a decision-support system, and systems for clinical trials are beginning to fade. Each patient-physician encounter, each investigation, each laboratory test, and each treatment in medical practice constitutes, in principle, an experiment. Ideally, we learn from each experiment. Paper as a medium to record data limits our ability to exploit that potential. Electronic medical records will facilitate research that relies on data recorded in routine medical practice. The potential and challenge, however, of Medical Informatics lays in its ability to close the loop between clinical practice, research, and education.

References

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