MED. INFORM. (1993), VOL. 18, NO. 2, 131–142

Decision support for drug prescription integrated with computer-based patient records in primary care

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(*Received October 1992*)

Abstract. A conceptual model of an information system that integrates a controlled vocabulary, a patient database, and a knowledge base is described. Methods, design and components for the implementation of the system are discussed. It is argued that the key issue for the successful introduction of computer-based decision support in primary care today is integration with a computer-based patient record. Also important is that the knowledge acquisition process is based on the general practitioner's real needs. This has been achieved by, first, providing general practitioners with real patient data from a series of retrospective database studies; and second, letting a panel of general practitioners select, discuss and decide which computer reminders to implement. A hybrid representation scheme was chosen for the knowledge base. The combination of a standard procedural representation (the so-called Arden syntax) for the reminder knowledge with a semantic net representation for the medical factual knowledge facilitates knowledge sharing with other systems and knowledge reuse within the system.

Keywords: Computerized medical records systems; Decision support systems; Drug therapy, computer-assisted; Primary health care.

1. Introduction

In an overview, Shortliffe defines a clinical decision support system as 'any computer program designed to help health professionals make clinical decisions' [1]. This means that any computer system that deals with clinical data or medical knowledge, in a sense, is intended to provide decision support. According to Shortliffe, decision support systems may be divided into three categories: (1) tools for information management (e.g. hospital information systems, bibliographic retrieval systems); (2) tools for focusing attention (e.g. laboratory systems that flag for abnormal values, pharmacy systems that detect drug interactions); and (3) tools for patient-specific consultation (systems that give advice based on patient-specific data). The third category is what many people in the first place would call decision support systems, but the limits between these categories should not be considered as distinct. On the contrary, one important reason why few of these systems have come into practical use is lack of integration between these three categories. Only when the physician is using the computer routinely to store and review data, and when the same computer system can give patient-specific advice based on those data, will decision support systems become widely accepted.

Also within the domain of drug therapy, there are these different categories of decision support systems and the same problems of lack of integration. Pharmacy information systems have been in use for many years both in hospitals and in

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community pharmacies. Controlled studies have shown that computerized drug monitoring systems can improve prescribing behaviour of clinicians [2]. Some of these systems have decision support functions belonging to the second category above, e.g. screening for drug interactions [3–5]. Most of these programs are intended for use at hospitals by pharmacists. Some programs have also been developed for use in primary care by the prescribing physician [6]. These programs typically take as an input a list of drugs entered by the user, search their database for possible interactions within each drug pair in the input list, and give an output list that specifies pairs of drugs that potentially interact. Few of these programs give any advice about the clinical significance of the interactions and how to manage the potential adverse effect of the interaction, or indicate which patients are at high risk for being harmed by the interacting drugs. Probably the most serious shortcoming of these drug interaction computer programs is that they are not integrated with computer-based medical records systems [7].

Obviously, a system that can give the decision support automatically, retrieving interaction data from the drug knowledge base and prescription data from the patient database, would be much more useful for the prescribing physician. The positive impact of such systems has been shown in controlled studies [8, 9]. Lack of standardization and compatibility, and unwillingness of the vendors to allow access to their drug databases, are some factors that have made integration with patient records difficult until now [10].

In a series of retrospective database studies the real need for decision support in primary care has been investigated at a health centre in suburban Stockholm, the Kronan Health Centre. The practice has seven general practitioners and two doctors on vocational training, and it has been using computer-based patient records since 1984.

One study [11] showed that potential drug interactions occur in 12% of patients at risk (those receiving two or more concurrent drugs), and that 1·9% of all drug prescriptions result in a potential drug interaction. In particular, the rate of potential drug interactions for elderly patients was very high, suggesting that adverse drug reactions may be a serious health problem among the elderly. The results are comparable with those reported by others. In three studies from primary care the rates of potential drug interactions for patients receiving two or more drugs were 29·5, 24·3 and 42·0%, respectively [12–14]. Another study reported 2·2% prescriptions of adversely interacting drugs in relation to all prescriptions [15].

Another database study, performed at the Kronan Health Centre, showed that several drugs excreted by the kidneys were prescribed to elderly people with impaired renal function. Out of a list of 24 generic drugs that should be avoided or given in reduced dosage to patients with impaired renal function, 11 drugs had been prescribed to patients having an estimated creatinine clearance, calculated from the serum-creatinine value, < 50 ml/min. Altogether 249 patients were involved during a 6-year period.

The results of these studies have several implications for the design of a drug-prescription decision support system. First, it is obvious from the results that there is a need for decision support. Second, the decision support system should not only identify drug problems, but also give some advice about the clinical significance of these problems and give some recommendations of what kind of actions are appropriate to take, to avoid adverse effects. Third, the decision support should focus on drug treatment of elderly people with multiple drugs. The system should consider the functional and metabolic alterations that accompany ageing, such as decreased hepatic and renal function. Recommendations of dose adjustments according to these alterations should be included. Fourth, the decision support system should be integrated with the patient information system used. An integration of the drug knowledge base with the patient database makes it possible to automate the interaction control and to give the physician alerts or computer reminders when potential interactions or other drug problems occur.

Based on the experiences of these studies we have developed a decision support system for drug prescription in primary care. The system is data-driven and integrated with the computer-based patient records. A knowledge base has been developed in which the factual medical knowledge is separate from the knowledge of alerts and reminders. The factual medical knowledge covers all drugs, their potential interactions, etc., while the reminder knowledge has been focused on the needs of the prescribing physicians according to the results of the database reviews.

2. A drug decision support scenario

During the consultation the physician decides to prescribe amiloride to a patient suffering from heart failure. When he starts prescribing the drug from his video terminal in the consulting room, the medication list of the patient is displayed on the screen. In this situation he may want to check the drug interactions among the current medications on the list, before or after he has chosen the new drug to prescribe. Furthermore, if the patient has impaired renal function he wants to be reminded of the potential risk to prescribe amiloride.

So, besides ordinary information about drugs such as generic name, synonyms, package size and price, the prescription system provides more sophisticated decision support which integrates information about the patient with knowledge about the drugs. First, the decision support system must be able to screen a medication list in the medical record and compare it with facts stored in the knowledge base of the system. Second, the system must be able to retrieve certain information from the patient database (about renal function here) related to the drug prescribed, apply some knowledge stored in the knowledge base, and if certain criteria are fulfilled give a reminder to the physician on the screen.

3. Conceptual model of the system

We will in the following present a conceptual model of the integrated decision support system. According to that model the system has three main components: the patient database, the data dictionary (controlled vocabulary) and the knowledge base. The basic component of the data dictionary is the medical term, the basic component of the patient database is the medical event, and the basic components of the knowledge base are the medical fact and the medical logic module (figure 1). The data structures and representation schemes that have been defined for these basic components are outlined in §§ 3.1–3.3. One or two practical examples have been chosen to show the structures: one medical term, 'amiloride', which is a cardiovascular drug; one medical event, 'prescription of amiloride'; and two pieces of medical knowledge, the medical fact that 'amiloride' is contraindicated in 'kidney failure', and a medical logic module which is a reminder about this contraindication. A frame-like (object-orientated) representation scheme was chosen for the data structures for medical terms and medical events. The knowledge

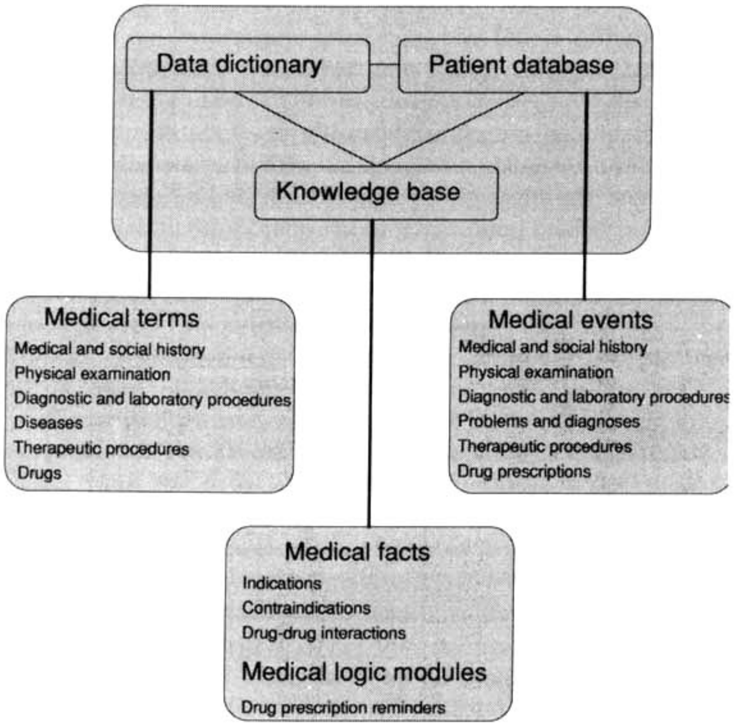

Figure 1. A conceptual model of a system that integrates a controlled vocabulary (data dictionary), a patient database and a medical knowledge base. The principal components are the medical terms, the medical events, the medical facts, and the medical logic modules.

base has two kinds of representation schemes: a semantic net for factual knowledge, and a frame-like representation according to the Arden syntax [16] for the reminders.

3.1. *Controlled vocabulary*

The controlled vocabulary of the system contains all medical terms needed to represent clinical data in the patient database and medical knowledge in the knowledge base. The medical terms of the system represent a subset of the entire medical nomenclature. In particular the controlled vocabulary of this system will comprise a subset of a national Swedish medical terminology database, which is under development. For that terminology database a structure has been proposed, which includes 10 main categories of medical terms (anatomy, organisms, medical history, symptoms, physical examination, diagnostic procedures, diagnoses, medications, therapeutic procedures, health care), and a standard record format which includes the following fields: unique identifier, preferred term, status, source, date, revision date, semantic type/category, description/definition, lexical variants, synonyms, related terms, mappings to national or international classifications and coding systems, and translation to other languages.

Sample MEDICAL TERM

identifier: (unique id: term_id)
preferred name: (amiloride)

synonyms:	(Milorid, Midamor)
semantic category:	(cardiovascular drug)
mappings:	(ATC: C03DB01)

3.2. *Patient database*

A medical event represents a medical action taken by a provider for a patient at a certain time, e.g. a diagnosis, a drug prescription, or a laboratory test. According to the model an event is regarded as a relation between three entities: the patient, the contact, and the medical term. A contact can be an encounter, a telephone call, or any other notation of a contact between a provider and a patient. The attributes of the contact (provider, date, site, type) specifies the context in which the medical action takes place.

Sample MEDICAL EVENT

identifier:	(unique id: pat_id,event_id)
patient:	(unit number: 111111-1111)
contact:	(date: 25 September 1992)
	(site: Health Centre)
	(type: scheduled visit)
	(provider: Dr NN)
type:	(drug prescription)
medical term:	(dictionary term: amiloride)
attributes:	(problem: no 1 = heart failure)
	(time: 2:00 PM)
	(route: tabl)
	(dose: 5 mg)
	(frequency: 1 tabl daily)
	(quantity: 100)
	(iteration: 4)
	(comments: 'heart strengthening')

The particular event is characterized by a set of properties (attributes) such as the time when it occurred and the value (numeric, textual or other). The corresponding data structure will be stored in the database as a separate unit. Conceptually, the medical record can be regarded as a collection of events, which are specified according to patient, source (provider), time and problem. Different documents in the medical record, such as medication list, laboratory report, and progressive notes, correspond to different views of the database of events.

3.3. *Knowledge base*

There are two separate parts in the knowledge base corresponding to two different types of knowledge: the factual medical knowledge and the knowledge about how the medical knowledge should be applied to a particular clinical situation. The latter type of knowledge will be called situation knowledge.

For the representation of factual knowledge we have chosen a declarative representation form, namely a semantic net. The semantic net has nodes and links, which denote objects and their relations. Possible nodes are medical concepts expressed as medical terms in the controlled vocabulary of the system, the data

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