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ABSTRACT FORM

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I_I Data Presentation I_I ________________

Title: HELP/PATHLAB Integration - A decade of experiences using an EXPERT SYSTEM interfaces to a CLINICAL LABORATORY SYSTEM

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p1 For the last decade, we have been using a system for automated medical decision-making which is interfaced to a computerized clinical laboratory system. The hospital based expert system is known as HELP (Health Evaluation through Logical Processing) and this central patient information and decision-making system communicates directly with a commercial clinical laboratory system (PATHLAB). The resulting system thus has test ordering, results reporting, and charge capture capabilities as well as automated interpretation of clinical data, alert generation, and diagnostic functions.

There are major advantages for an expert system which is integrated with an on-line clinical database; one of the most important is the fact that the decision-making capabilities can be automatically evoked whenever new data are added to the patient record. We refer to this mode of activation for the decision logic as being "data driven". This means that a user receives suggestions and decisions whenever appropriate logical requirements specified in the expert knowledge base are satisfied by data which exist in the patient record. This happens whether the user requests the interpretations or not. Because data exist which satisfy the logical requirements for a specific decision, the decision is generally easily validated and believable. Even though the expert logic may not exist for all possible interpretations or alarms, those decisions which are produced are generally valid and timely.

Because the physician or nurse automatically receives these decisions, alerts or interpretations as part of the reporting system, they are noticed by the health care professional even though they may sometimes present information which has already been perceived by an alert physician or nurse.

In the sections which follow, we shall describe the overall function of the HELP system, then discuss the interface requirements between the central decision-making system and the laboratory system and then illustrate the types of automated decisions which the system produces.

HELP DECISION SUPPORT SYSTEM

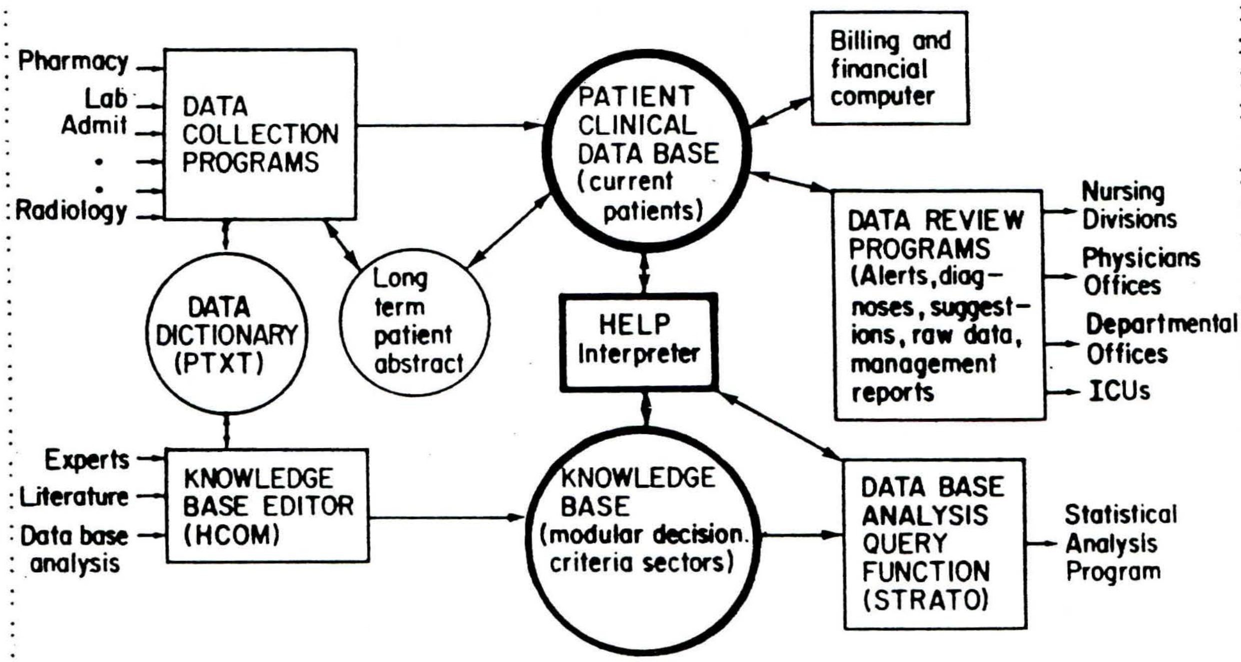

Figure 1: An overview of the components of the HELP system

The HELP system:

As can be seen in figure 1, the system essentially consists of three main parts: a comprehensive clinical patient database, a separate knowledge base which contains expert logic, and an interpreter which controls the evaluation of the expert knowledge.

Those elements in the upper half of figure 1 (data collection programs, the long term patient file, the current clinical patient file, the reporting functions and the link to the financial system) are fairly standard components which are found in many hospital information systems. The central data base should integrate data from and communicate with computer systems in ancillary departments in order for test ordering and results review to be possible at all terminals. We have chosen to use the Tandem computer for the central system because it is easily expandable and has built in hardware redundancy which helps to insure that the system is always operational. In our 520 bed hospital we presently have 470 terminals or printers attached to a central system with six CPUs. There are multiple microprocessors attached to the central system which may act as signal processors or contain destributed copies of the central database for selected patients (e.g. those in an intensive care unit).

The long term file contains on-line data for all previously admitted patients and consists of abstracts of clinical and demographic information likely to be useful if a patient is readmitted. The clinical data base contains all data gathered during the current admission, and after the patient is released, this record is stored in archives which are available for statistical assessment. All clinical data are stored in a coded format which is defined using a data dictionary. This coded format is necessary in order to allow the logic contained in the expert knowledge base to accurately reference specific data which may be stored in the patient data base.

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The elements in the lower half of figure 1 represent the additional features necessary for a decision support system (knowledge base editor, knowledge base and the HELP interpreter). Expert knowledge can be obtained from the opinion of an expert, medical literature, or statistical experience represented in the patient database. The knowledge is stored as frames or "HELP sectors" which contain the logic necessary to make a specific decision. The medical knowledge base supports a variety of decision-making models (IF...THEN...rules, patient specific probability revision, query for missing data etc.) and allows the medical expert to enter criteria using a high level language contained within the knowledge base editor.

When new results are stored in the patient record or a specific block of the knowledge base is otherwise activated, the HELP interpreter evaluates each item of logic in the appropriate HELP sectors and queries the patient database to see if the data specified in the expert logic exist and meet the criteria specified in the logic. The sectors themselves contain the logic which determines how they are to evaluated. An arithmetic statement can be used to perform tasks ranging from Boolean logic to calculation of a discriminant function. Chronologic statements can be used to retrieve the time of a specified event so that time may be used for data limitations or action flags. Existence statements use the presence or absence of a piece of data rather than the value as the basis for logical calculations. Data retrieval statements are used to search the clinical database for specific items within specified time limits. These search items may also trigger the evaluation of additional HELP sector modules or ask for missing but necessary data. When all necessary items for a decision are satisfied, the interpreter forms a new data string which reflects this result and stores the string in the patient record as well as activating other specified reporting mechanisms.

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Interface to the clinical laboratory system:

Whenever a patient is admitted to the hospital, moved to a new room, or discharged from the hospital, the central computer system notifies the laboratory system of these changes. In the past, laboratory tests were ordered using mark sense cards which were read directly by the laboratory computer. In order to unify the procedures for ordering all types of ancillary services, we have changed this procedure. In the future all laboratory tests will be ordered from terminals connected to the central system. These requests with associated information (room number etc.) will then also be transferred to the laboratory system. The laboratory system maintains its own database of test results for internal integrity, quality control and operational functions, but results are reported by transferring the data to the central machine and storing the data in the comprehensive clinical data base. Transferring a laboratory result to this central computer enables the charge capture mechanism in the central machine and triggers the appropriate expert logic. The segments or blocks of this expert logic which are activated depend upon the type of test result which has been transferred. Thus the communication between the systems is two-way; the laboratory system receives information from the hospital ADT (admit-discharge-transfer) system and sends its results to the central database system.

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p 2:

Experience with the decision-making aspects of the system:

Rather than dwell upon the specific types of individual decisions that the system is capable of making, we shall describe one of the best received and appreciated applications: pharmacy-laboratory alerts. This application illustrates the strengths of an integrated system with decision-making capability. When drugs are prescribed, the

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pharmacist enters these prescriptions into the computer. This entry activates decision logic which is based upon a combination of current medications as well as laboratory results. If the prescription is for a diuretic, a group of HELP sectors is evaluated which use information concerning diuretics in the expert logic. One of these sectors ascertains whether the prescribed drug is a potassium sparing diuretic and whether the patient's present serum potassium level is within normal limits. If both of these criteria are not met, the computer suggests to the pharmacist that a potassium supplement may be advisable. If a drug which can potentially reduce kidney function (e.g. Gentamicin) is prescribed when the serum creatinine or BUN levels are already high, the pharmacist is alerted that a different drug may be preferred.

After the pharmacist verifies that the suggested contra-indication is valid, the prescribing physician is notified. In approximately 85% of these instances the physician changes the prescription. In our hospital population we find that 4% of the drugs and 2% of the patients recieve pharmacy related alerts. A significant fraction of these alerts involve pharmacy-laboratory interactions. A study which estimated the costs associated with stay-extending contraindications showed that the entire pharmacy surveillance expert system was cost effective by a four to one margin. A second study showed that those patients with abnormal laboratory values came back into the normal range significantly faster if the physician or nurse was notified by the HELP system. Based upon these formal evaluations as well as the broad acceptance of the system which has occured as physicians have learned how to use the system, we feel confident that expert systems will play an expanding role in the proper utilization of laboratory results.