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Computer concepts

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Computerized Medication Monitoring System

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A computerized medication monitoring system for alerting and warning of potential adverse drug reactions is described.

The system integrates computerized data on each hospital patient (medications, clinical laboratory, blood gas, ECG, allergies, diagnosis, etc.) and returns to the pharmacist warning messages and suggestions regarding patient drug therapy. The broad data base allows for nearly complete drug therapy monitoring. When a warning message is received, the pharmacist contacts the physician or nursing staff and explains the potential problem. The system also generates prescription labels and patient drug profiles which are used in a unit dose dispensing system.

Five percent of 13,727 patients monitored have had drug alerts. Of these alerts, 44.9% were drug-laboratory contraindications and only 28.9% were drug-drug interactions. Of the 690 alerts received, 77% resulted in the physician changing the patient's therapy.

Key words: Automation, data processing, computers; Drug information; Drugs, adverse reactions; Patient information; Pharmacy, institutional, hospital

Adverse drug reactions are a recognized health care problem. It has been shown that as the number of drugs administered increases, the risk of adverse drug reactions increases rapidly. Cluff and associates[1] reported that hospitalized patients receiving 0-5 drugs during their hospital stay experienced adverse drug reactions 4.2% of the time, while patients receiving 16-20 drugs experienced adverse drug reactions 40% of the time. Drug surveillance studies currently are being conducted to detect and evaluate adverse drug reactions, their clinical significance and factors which predispose a patient to a reaction. Jick and associates of the Boston Collaborative Drug Surveillance Program,[2] Cluff and associates,[1,3,4] and the Kaiser-Permanente Foundation[5] are some of the groups involved in this epidemiological study of drugs and their adverse effects.

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The difficult role of prevention of adverse drug reactions is the responsibility of the physician, the pharmacist and the nurse. The physician often lacks time to obtain needed drug prescribing information. The pharmacist does not have convenient access to vital information in the patient chart that is required to monitor for proper drug therapy (i.e., diagnosis, laboratory data, weight, etc.). The nurse often lacks both adequate time and knowledge of drugs. As a result, gathering of drug prescribing information and screening for drug contraindications often occur only after the patient already has received the drug.

Computer programs have been developed to aid in the prevention of adverse drug interactions. Cohen at Stanford University Medical Center[6] and Maronde and associates at the Los Angeles County-University of Southern California Medical Center[7] have two of the best developed computerized drug alert systems. These computer programs search for matches between drug pairs in the patient's profile via a drug-drug interaction matrix. When matches are found, "alert" reports are generated to notify the physician of a potential drug-drug interaction. Although it is known that drug monitoring includes more than drug-drug interactions, the lack of an adequate patient data base has prevented these computer programs from evaluating other contraindications. This paper describes a recently implemented pharmacy computer system which uses the patient's complete medical record to provide alerts on potential adverse drug reactions. By considering more of the patient's data, better and more complete drug monitoring can occur. This system monitors not only drug-drug interactions, but also drug allergies, drug laboratory interactions, drug-disease interactions, digitalis therapy, aminoglycoside therapy and anticoagulant therapy.

Description of System

The LDS Hospital in Salt Lake City, Utah, is a 550-bed hospital with a clinical computer system which gathers data from many areas to form a broad patient data base.[8] Data are gathered both automatically and manually through interactive programs from many hospital data sources (Figure 1). Most data are entered automatically or by paramedical personnel and therefore do not require physician effort. Patient histories are computerized and are self-administered.

The pharmacy uses a unit dose dispensing system with a 24-hour supply. Drug orders are sent from the nursing divisions to the pharmacy where the pharmacist enters them via a terminal into the patient's computer file. To enter a drug order, the pharmacist first enters the patient's hospital number. The patient's name is displayed for verification. Next, the name of the drug or the drug's code number is

Figure 1. "HELP" computer system

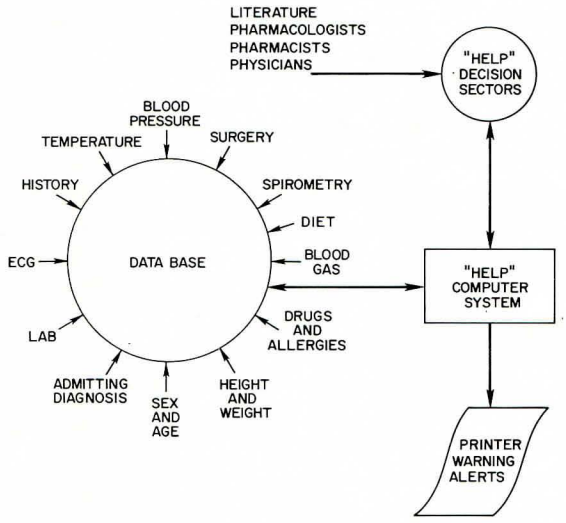

Figure 2. "HELP" sector which alerts the physician when a patient is receiving an aminoglycoside and renal function is not being monitored (see text discussion)

Message: Suggest that serum creatinine is checked every three days when using gentamicin, kanamycin, streptomycin, or tobramycin

Final Evaluation: A and not B

Items:

A	Anti-infectives, (A) aminoglycosides, (B) neomycin, (C) current. Boolean statement: C and A and not B; order must be at least 10 hours old.
B	(A) creatinine clearance, (B) serum creatinine, (C) aminoglycoside blood level. Boolean statement: A or B or C; must be in the last three days.

entered. Trade names, generic names or abbreviations may be entered. For example, one may enter the generic name (hydrochlorothiazide), a trade name (Esidrix, Hydrodiuril, etc.), an abbreviation (HCT) or a drug code (130104). Regardless of which of the above is entered, "Hydrochlorothiazide x mg" always is returned. Subsequently, the dose, route and schedule of administration are entered. Upon completion of entering the drug order, the prescription is redisplayed for confirmation. When a drug order is discontinued, the pharmacist enters this information thus keeping the patient's medication profile current.

Drug allergies written in admitting orders are sent to the pharmacy where they are entered into the computer. The pharmacist may enter an allergy to a particular drug or to a class of drugs (e.g., tetanus toxoid, penicillins).

A unique computer program allows the integration of the patient's computerized data for the purpose of making clinical decisions. The HELP (Health Evaluation through Logical Processing) computer system was developed to allow experts in a medical specialty to define the rules and criteria for medical decision making. Once established, the criteria set is applied to all patients. Alerts are generated when the previously defined criteria are met.[9,10]

Criteria for each decision are established by pharmacologists, pharmacists and physicians who review the literature and incorporate their clinical experience into a given decision (Figure 1). These criteria become unique segments of logic (HELP decision sector) having specific diagnostic messages associated with them. HELP sectors are stored on a magnetic disc and then automatically applied to all patients receiving drug therapy. Each HELP sector consists of a message, a final evaluation statement, and data and logic items (Figure 2). When the sector is "true," the alert message is returned to the user. The final evaluation designates the items required for the sector to be true. Figure 2 shows some of the types of items that are possible. Item A defines a search for the presence of a class of drugs (anti-infectives), a subclass (aminoglycosides), and excludes the specific aminoglycoside, neomycin. The Boolean logic[a] statement associated with item A controls the data search by requiring that the patient is currently (C) receiving an aminoglycoside (A) that is "not" neomycin (B). Item A also specifies that the drug order be at least 10 hours old. An item may define a mathematical manipulation or a special pharmacokinetic function to determine drug effects on the individual patient. Data from the entire patient data base may be used in forming logic. For example, item B of Figure 2 retrieves patient creatinine clearance, serum creatinine and aminoglycoside blood level data.

The broad data base and the flexibility of the HELP system allow for complete drug monitoring. For example, concomitant administration of 6-mercaptopurine and allopurinol may result in 6-mercaptopurine toxicity unless the dose of 6-mercaptopurine is reduced.[11] The HELP sector which monitors for this drug-drug interaction makes a dose calculation (mg/kg/day) to determine if the necessary dose reduction has occurred. A warning message is given only if the physician has not already made the necessary dose reduction. For the concomitant administration of tetracycline and antacids,[12] the sector checks to insure that the tetracycline is being given orally and that the antacid also is scheduled. At the time a drug or an allergy is entered into the patient's file, it is checked automatically by all the HELP sectors for alert conditions. When the criteria for an alert are met, a warning message is displayed on the computer terminal and a hard copy of the message is printed. For example, "allergy history suggests penicillins may be contraindicated," would appear on the terminal if ampicillin were entered on a patient allergic to penicillins. If no contraindication is found, the computer requests the scheduling of the next drug order.

Although the computer automatically monitors drug therapy, occasionally the pharmacist may still have a ques-

[a] Boolean logic involves logical true/false determinations by the specific references from an item list with logical operators (i.e., and, or, not, greater than, less than).

tion about a drug order. The pharmacist may instruct the computer terminal to print information about a patient's laboratory data, admitting diagnosis, diet, decision list, weight, height, age, sex or room assignment. For example, the computer may give a warning message that the patient is receiving digitalis and has a low serum potassium concentration. In this case, the pharmacist may inquire from the system the previous potassium concentrations or the patient's serum creatinine.

Simultaneously, when confirmation of a drug order is given, it is stored in the patient's file and a prescription label is generated by a printer. Prescription labels are generated for all non-floor stock drug orders, and are used on medication that is sent to the floor before the next unit dose medication drawer exchange.

A computer medication profile is kept for each patient. This profile allows the pharmacist to review, from a terminal, all drugs currently being given to the patient, all discontinued drug orders, or drug allergies. A hard copy of the current medication profile may be generated on a line printer in the pharmacy (Figure 3). Medication profiles may be produced either for an individual patient or for a nursing division. Typically, a pharmacy technician will request profile printouts for a given nursing division to be used to fill the unit-dose medication carts. The pharmacist is responsible for followup on every drug alert. After receiving a warning message, he may review the patient chart and discuss the problem with the physician, leave the computer-generated warning message with a written note in the patient's chart for the physician, contact the appropriate medication nurse, or refer the warning message to another pharmacist for followup.

Figure 4 is an example of a HELP sector which monitors digitalis therapy. Item A requires that the patient be currently receiving digitalis therapy, item B is for potassium supplement, while item C specifies a search for the most recent serum potassium laboratory result. The final evaluation statement defines the criteria for generating an alert for this sector. That is, if the patient is receiving digitalis (item A), is not receiving a potassium supplement (item B), and has a potassium level (item C) of less than 3.4 mEq/liter, the warning message is given suggesting that a potassium supplement be ordered.

Figure 3. Example of a computer-generated patient medication profile used in the unit dose system (see text discussion)

PATIENT MEDICATION PROFILE
14:43 6/11/76

Test, Terry Pt. Number: 123456 Room: 441
Dr. Warner, Homer R. Ht: 160 cm Wt: 80.0 kg Age: 30
Sensitivities: Penicillins

1. Ampicillin 250 mg, oral, q.i.d.
2. Colace 100 mg, oral, q.d.
3. Digoxin 0.250 mg, oral, q.d.
4. * Meperidine 100.0 mg, i.m., q. 4 h. prn, floor stock
5. * Flurazepam 30 mg, oral, h.s. prn, floor stock

Figure 4. "HELP" sector which alerts physician to patients who are receiving digitalis, are not receiving potassium and have a low serum potassium (see text discussion)

Message: Suggest potassium supplement, as patient's low serum potassium concentration may result in digitalis toxicity

Final Evaluation: A and not B and C LT 3.4

Item:

A	Digitalis (B) Current
B	(A) Potassium supplement (B) Current
C	(A) Serum potassium concentration last

Table 1. Results of Computer Alerts, Their Causes and Actions Taken

Sector Type	Sectors No.	Sectors %	Warnings No.	Warnings %	Therapy Changes (%)
Drug-drug	52	34.9	199	28.9	79.9
Drug-allergy	44	29.5	112	16.2	56.3
Drug-laboratory	30	20.1	310	44.9	79.7
Drug-disease	9	6.1	0	0	0
Drug-dose	6	4.0	50	7.3	94.0
Drug-diet	4	2.7	9	1.3	77.8
Drug-route	2	1.3	2	0.3	100.0
Drug-interval	1	0.7	3	0.4	66.7
Alternate drug	1	0.7	5	0.7	100.0
Totals	149	100	690	100	77.1

Total number of patients monitored: 13, 727
Total number of drug warning messages: 690 (5.0%)

Evaluation

There are 149 drug-monitoring HELP sectors in use. HELP sectors are continuously being added to enlarge or revise update areas of drug therapy monitoring.

A ten-month experimental program was completed seven months ago, where all drugs ordered on two medical divisions and one surgical division (86 beds) were monitored. The system has since been expanded to include almost all hospital patients. The results of the data collected in the first 16 months of monitoring are shown in Table 1. A total of 88,505 drug orders for 13,727 patients have been monitored. It was found that 690 (0.8%) drug orders resulted in a warning message on 5.0% of all patients. Physician acceptance of the system has been enthusiastic. Five hundred thirty-two (77.1%) of the warning messages resulted in a change in therapy. Patient-reported allergies which the physician later believed not to be true allergies accounted for 48 (30%) of the warning messages that did not result in a change in therapy. Compliance corrected for this "soft" allergy data is 82.9%.

A comparison of types of HELP sectors and numbers of warning messages received is shown in Table 1. An important need to integrate laboratory data to monitor medication therapy is indicated by the fact that while HELP sectors involving both drug and laboratory data constitute only

20.1% of all medication HELP sectors, they are responsible for 44.9% of all warning messages received.

The success of this program, in large measure, can be attributed to the interface of the pharmacist with the computer system. The pharmacist uses the warnings produced by the computer to alert him to problems he should investigate. It is his responsibility to follow up on all warnings. He keeps a record of each alert, the effect of the alert on patient therapy and any adverse reactions that occur. This information is subsequently used to determine needed changes and updates in the HELP sector logic and provides statistics on physician acceptance. The computer, therefore, does not directly interface with the physician nor is it dictating to the physician how to practice medicine. Instead, it serves as a means of education and of constant surveillance, communicating with him through the pharmacist.

Examples of Usefulness of System

The following clinical cases will serve to illustrate the system's utility.

> Patient A.H. was started on gentamicin 80 mg i.v. every eight hours. Since neither a creatinine clearance, a serum creatinine, nor a gentamicin blood concentration was available on the patient, the computer advised that the serum creatinine should be monitored. The test was ordered by the physician giving a result (serum creatinine 10.6 mg/100 ml) indicating severe renal failure. Therapy was altered because of this information. Toxic concentrations of gentamicin would have been reached had the warning message not been given.

> Patient M.H. was admitted with a diagnosis of severe congestive heart failure and peptic ulcer disease. As part of the patient's therapy a low sodium diet (500 mg/day) was ordered, but hourly doses of an antacid containing large amounts of sodium also were prescribed. The computer suggested that an antacid with a low sodium content be used instead. The physician felt this was a good suggestion and changed the antacid prescription.

Both of these cases could have been detected by a pharmacist monitoring therapy with the patient's chart. The medication monitoring system, however, allowed the pharmacist to detect these problems in the normal course of filling the prescription order. Additional pharmacist time was not required to detect these problems. Indeed, 30 seconds is the average time needed to enter a drug order into the computer, have it type a label and process the data for possible contraindications.

Conclusion

The medication monitoring system makes the pharmacist more efficient and accurate in monitoring patient drug therapy. By monitoring each patient automatically, the system helps tedious, sometimes difficult, monitoring, while enabling the pharmacist to monitor more patients. It warns the pharmacist of potential problems much more quickly than do manual monitoring techniques. Oversight errors also are reduced.

Computerized monitoring systems that can detect only drug-drug interactions overlook many important problems. Table 1 shows that drug-drug interactions accounted for only 28.9% of our alerts. A significant need to use laboratory data in monitoring patient drug therapy has been shown. Of all alerts, 44.9% involved laboratory data.

Our findings have resulted in a hospitalwide expansion of the medication monitoring system. The cost of the computer system is $0.35 per patient day and is included in the pharmacy charge for medication. Future efforts will be aimed at the expansion of HELP sector logic to make a more complete drug monitoring system. Cost justification studies and studies to determine the effect of the medication monitoring system on patient care are underway.

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The primary objective of this column is to present basic information and principles of electronic data processing (EDP).

The second objective of the column is to provide the hospital pharmacist involved with data processing with the mechanism to interchange information. Readers are urged to submit contributions on their work with EDP.

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