ASSESSING THE EFFECTIVENESS OF A COMPUTERIZED PHARMACY SYSTEM

Reed M. Gardner, PhD
Professor of Medical Informatics
LDS Hospital/University of Utah
Russell K. Hulse, RPh, MBA
Associate Director of Pharmacy
LDS Hospital
Keith G. Larsen, RPh
Director of Pharmacy Computerization
Intermountain Health Care, Inc

Abstract

Quantitative and qualitative assessments were conducted to determine the value of a computerized pharmacy system in operation since 1975. Patient prescriptions were processed and critiqued for contraindications. It was found that the number of medication monitoring alerts increased over the 15 year period. Physicians have increasingly complied with the changes recommended by the computer system and want to expand the computer capability. Integration of patient data from multiple sources, especially clinical laboratory, was essential to making the medication monitoring system effective. A Benefit/Cost analysis showed that there was about a 4 to 1 Benefit to Cost Ratio for the system.

Introduction

As medical knowledge has expanded and the acuity of hospitalized patients has increased, physicians have had an ever-increasing amount of patient data to evaluate and assess. One result from this expansion of knowledge has been the application of computers for classification and analysis. The computerized pharmacy alerting system at LDS Hospital [1] has gained wide physician acceptance and is now financially subsidized by the hospital administration.

Investigators have pointed out the value and conceptual worth of computerized pharmacy systems [2-9], such as the MENTOR system [2], the Boston Collaborative Drug Surveillance Program [6] and outpatient pharmacy systems [8,9]. Educational methods have been shown to improve prescribing behavior, but may not be long lasting [4]. The work presented here resulted from quantitative and qualitative assessment procedures and illustrates the benefits of a computerized pharmacy system.

Materials and Methods

The LDS Hospital in Salt Lake City, Utah, is a 520 bed facility with a clinical computer system (HELP) that gathers data from many services within the hospital [10,11]. The result is a rich clinical patient database. Data in the system is obtained from automated equipment in clinical laboratories and intensive care units, as well as from pharmacy, surgery, multiphasic screening areas, admitting, and medical records areas [10,11].

Figure 1 is a flow chart of the pharmacy module of the HELP system in operation since 1975. Medication

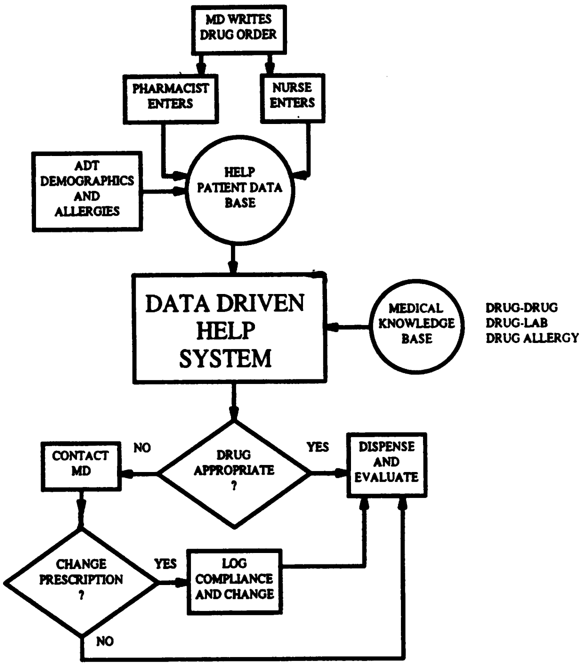

Figure 1 Flow Diagram of Computerized Medication Monitoring System

orders are entered by hand into the patient chart, then are entered into the HELP computer system by a pharmacist or a nurse [10,11]. The integrated database and decision-making capabilities of the HELP system made it possible to evaluate the medication orders for Drug-Drug, Drug-Laboratory and Drug-Allergy interactions. If the drug is appropriate, the pharmacist dispenses the medication. If the computer indicates that the medication is not appropriate a pharmacist contacts the prescribing physician.

Assessment of the effectiveness of the system is based on five evaluations: 1) the number and type of

0195-4210/90/0000/0668$01.00 © 1990 SCAMC, Inc.

alerts, 2) Physician compliance with pharmacy alerts, 3) Physician attitudes toward the pharmacy system, 4) The type of patient data used to make decisions, and 5) Benefit/Cost estimation of the alerting system. The procedure for each of the five assessments is presented below.

Number and type of alerts

Statistics on the number and type of each generated alert have been kept since the system's inception in 1975. In 1979 the alerts were subdivided into two categories: informational and action oriented. "Informational" alerts were important to the care of the patient, but did not require immediate therapy change, "Action oriented" alerts required prompt physician interaction to change therapy. With each "action oriented" alert, a clinical pharmacist contacted the responsible physician for a detailed assessment of the medication order.

Physician Compliance Rates

The attending pharmacist was responsible for assessing physician compliance with the alert. Assessment of physician compliance rates were based on data derived from the physician compliance log shown in Figure 1.

Physician Attitudes

Evaluation of physician attitudes toward the HELP system was based on a questionnaire sent to 360 staff members in the Spring of 1989 [12]. Several questions about the value of the pharmacy system and its effect on their practice were asked.

Data Sources Required for Pharmacy Alerts

Alerts were categorized according to the sources of data required to trigger them. Drug-Drug alerts compared new medication orders to data in the patient's medication profile. Drug-Allergy alerts required not only drug information, but also knowledge about the patient's allergies to medications. Drug-Laboratory alerts required knowledge about medications plus data from the clinical laboratory.

Benefit/Cost Analysis

A charge of $0.35 per monitored patient day was instituted to cover the cost of the computer resource, and developmental costs for the program were funded by a grant from the Public Health Service. As a result, the denominator of the Benefit/Cost ratio was readily determined.

Evaluating the benefit of the alerting scheme was much more difficult [13]. Two clinical pharmacists from LDS Hospital and three clinical pharmacists from the University of Utah College of Pharmacy assessed the value of each alert using a modified Delphi approach [14,15]. The pharmacists were provided a list of current hospital costs and were asked to estimate probable complications resulting from each adverse drug reaction addressed in the alerting system. Each was then asked to assess the value of the alert to the patient in terms of dollar costs. They were asked to make this judgment in response to the question, "If this adverse drug reaction occurred in the patient, what would it cost to treat the adverse reaction?" No further instructions were given and each expert was asked to make an independent judgment of dollar value.

The benefit was calculated by using the dollar value of each alert. The dollar value was determined from an average of the five pharmacists responses multiplied by actual incidence rate of the alerts for a two year period. We noted that some alerts that were judged to be life threatening and had very high benefit as judged by the clinical pharmacists never occurred during the year. As a result, the effect of having these alerts were assumed to have no value. However, had they occurred, the computer system would have provided a lifesaving alert!

Results

Number and type of alerts

During 1989, LDS Hospital admitted 20,470 patients who stayed for a total of 114,108 days (average length of stay 5.58 days). Approximately 1.3 million doses of medications were given. Figure 2 plots the alerting experience at LDS Hospital from the inception of the computerized medication monitoring system in 1975 through 1989. In 1979, the logging of total alerts and

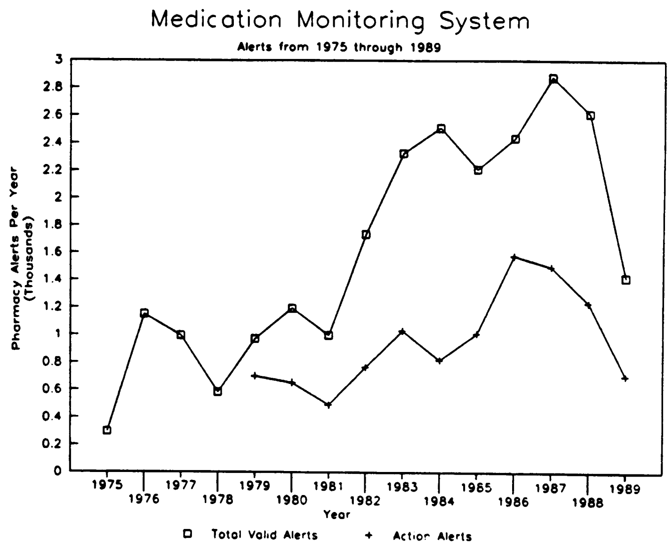

Figure 2 Alerts and "action oriented" alerts -- change over time

"action oriented" alerts was begun. Note that, except for the years 1988 and 1989, the number of alerts has grown almost continuously. In 1981 alerts decreased as the HELP system was transferred from the old hardware platform to the Tandem hardware. The downturns noted in 1988 and 1989 were due to changes in the software operating systems that reduced the effectiveness of some of the data driven capability of the HELP system. The situation causing the problem has now been corrected.

Physician Compliance Rates

Figure 3 plots the physician compliance rate to the pharmacy alerting system. The compliance rate in 1975, the first year of operation, was about 80% and dropped to about 70% in 1977. In 1979, the alert categories were changed so compliance assessments were made only from "action oriented" alerts. As a result, in 1979 the compliance rate jumped to about 90%. Since 1979, except for the year 1981 when we changed the HELP system to a new hardware platform, there has been a continual improvement in rate of physician compliance to alerts. In 1989 there were 703 "action oriented" alerts and all 703 resulted in physician compliance!

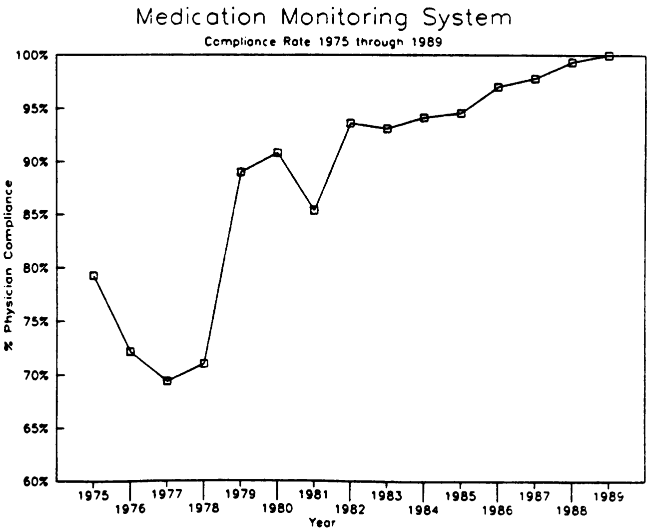

Figure 3 "Action Oriented" Alert Compliance Plot from 1979 through 1989

Physician Attitudes

Two hundred forty six of the 360 physician questionnaires mailed in the spring of 1989 were returned (65% return rate). The questionnaires provided a rich source of assessment data on a variety of subjects. The questions and responses regarding the pharmacy system are noted below.

When physicians were asked to rank existing computer features they ranked "Alerts that warn of potentially dangerous situations such as life-threatening laboratory abnormalities or drug interactions" at the top with a score of 4.63 (out of a possible high of 5). "Medication monitoring and generation of pharmacy alerts at the time an order is placed," was given a score of 4.34. When physicians were asked to rank what future computer features were needed, they placed "Direct physician access to the pharmacy knowledge base for prescription advice," with a score of 4.26, second only to expansion of laboratory alerting [16].

Physicians were also asked to rank the 10 features of the LDS Hospital computer system that most contributed to their professional practice. Table 1 shows that the pharmacy alerts ranked third.

Table 1
Physician Ranking of Computer Features

	1st	2nd	3rd	Score	Sum First 3 Choices
1. Lab Results	132	27	10	1,848	169
2. Vital Signs	11	36	35	1,264	82
3. Pharmacy Alerts	20	40	19	1,262	79

Data Sources Required for Pharmacy Alerts

Figure 4 shows the percentage of time each data source resulted in a pharmacy alert. Drug-Laboratory alerting had the largest percentage of alerts (55.5% of the time) while Drug-Drug interaction capability produced 36.3% of the alerts.

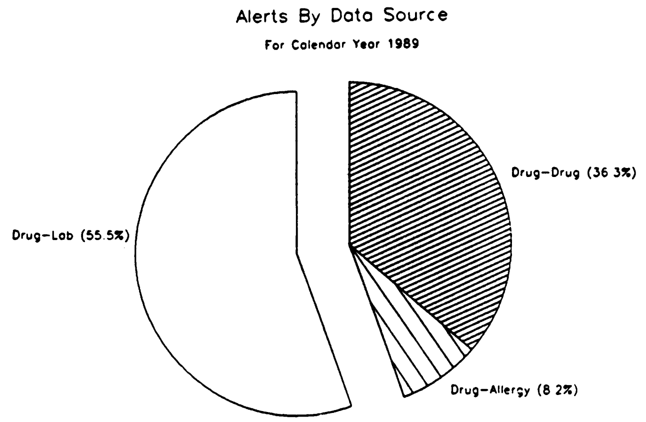

Figure 4 Pie Chart of Percentage of each Alert Type

Benefit/Cost Analysis

Benefit/Cost analysis was based on the assessments by five clinical pharmacists. Results of this analysis are presented in Table 2. Benefit for each type of alert was determined by averaging the dollar value estimates from the five clinical pharmacists. There were wide variations between the estimates of the clinical pharmacists because of their uncertainty about severity of the reaction. For example, with penicillin allergy it was necessary to evaluate two separate questions: 1) What was the incidence of reaction for those who "claimed" to have penicillin allergy? and 2) What was the severity of the reaction when a person with positively known penicillin allergy was given penicillin? Some patients think they are allergic to penicillin, because they get a skin reaction from ampicillin. Thus the incidence of true penicillin allergies from the population who think they have penicillin allergies may be only about 50%. On the other hand, for a patient known to have a penicillin allergy one could use a worst case analysis and assume that every patient given penicillin would have anaphylactic shock and could die. There is a continuum of reactions ranging from no reaction or a mild reaction to a severe reaction or death.

Table 3 summarizes the benefits and the Benefit/Cost ratio for the computerized alerting system. During the two-year experience, over 53,000 patients were monitored for more than 246,000 patient days. Less than 4% of the patients had medication alerts and less than 0.7% of the drugs ordered resulted in an alert. Charges of 35 cents per day resulted in the charge for service of just over $86,000 for the two-year period. Table 3 also shows the Benefit to the patient was more than $339,000, or a Benefit/Cost ratio of 3.94. Features that were felt to be of value but were not considered as benefits in this analysis included: 1) administrative support such as billing, dispensing, and printing of medication labels, 2) pharmacy data review and reporting capabilities used by nurses and physicians, 3) pharmacy support of other computerized decision support capabilities, such as the computerized microbiology system operating on the HELP system [17-19], 4) the printing of patient profiles, 5) reduced malpractice risks for physicians and the hospital, and 6) availability of the database for research.

TABLE 2

Experience with 24
most beneficial alerts -- 2 Years activity
that accounts for approximately 90% of the benefit

Rank by $ Value	Alert	# Compliance	$ Benefit Average 5 Experts	Total $ Benefit
1	Aminoglycoside Monitoring	256	360	92,160
2	K+ when Hyper Kalemic	85	380	32,300
3	Digitalis & Hypo Kalemia	90	341	30,690
4	K+ Spare Diuretic - Hyper K	43	590	25,370
5	Codeine Allergy	139	170	23,630
6	Penicillin Allergy	65	202	13,130
7	K+, Renal Failure	44	286	12,584
8	Gentamicin, Renal Status	19	651	12,369
9	Aspirin Allergy	67	170	11,390
10	Meperidine Allergy	53	170	9,010
11	TNC Antacids	178	49	8,722
12	Lomotil excess	35	235	8,225
13	Chloramphenicol	19	317	6,023
14	K+ with K+ Diuretic	14	360	5,040
15	Coumarin	28	157	4,396
16	Sulfonamide Allergy	20	189	3,680
17	KCl - Hypo K+ & HypoCl-	21	118	2,478
18	Morphine Allergy	13	170	2,210
19	Low Na+ Diet	14	148	2,072
20	Coumarin, Thyroid	17	100	1,700
21	Cholestyramine	22	55	1,210
22	NaF - Ca	30	25	750
23	Amp - Allopurinol	13	32	416
24	Laxative & Anti-Laxative	17	23	391
TOTAL for all 86 Alert Types		1,459		$339,752

TABLE 3

Computerized Alerting Experience
and Benefit to Cost Analysis

Patients Monitored	53,006
Patient Days Monitored	246,521
Drug Orders Monitored	312,518
Number of Alerts	2,110
% Patients with Alerts	3.98%
% Drug Orders with Alerts	0.68%
Cost per Patient Day for System	$0.35
Cost for 2 years Service	$86,282
Estimated Benefit (see Table 2)	$339,752
Benefit/Cost Ratio	3.94

Discussion

It was demonstrated that a computerized pharmacy system could be used in a clinical setting to the benefit of patients. Physicians appreciated and responded appropriately to the medication alerts. In addition there was a continuing growth in the number of alert conditions. The alerts could have resulted in a learning effect that would reduce the number of alerts over time. If there was a learning effect it was small. Tierney and associates have shown a similar lack of learning effect with a computerized ordering system [20]. Physicians were very responsive to the alerts and appreciated the "safety net" effect of the computerized system. In 1989, 100% of the "action oriented" alerts were responded to appropriately. A questionnaire determined that our physicians appreciated the alerts and wanted even more computerized capability. It become apparent through examination of the patient data used to generate the alerts that an integrated database with at least a link to the laboratory data was crucial. There seemed to be a salutary Benefit to Cost ratio. However, better methods need to be developed to prove the actual benefit of such a system.

Tierney, Shortliffe, and McDonald have pointed out the need for computer systems that aid physicians in their decision making [20,21,22]. The pharmacy alerting system described and assessed here is an important step in using computers to improve the care process. The use of such systems may improve the care process much as surgeons have found that there is "high cost for low frequency events" [23]. A computerized system is clearly the best "safety net" yet developed for such improvements.

References

1. Hulse RK, Clark SJ, Jackson JC, Warner HR, Gardner RM. Computerized medication monitoring system. Am J Hosp Pharm 33:1061-1064, 1976.
2. Speedie SM, Skarupa S, Oderda L, et al. MENTOR: Continuously Monitoring Drug Therapy with an Expert System. MEDINFO 1986 pp 237-239.
3. Knapp DA, Speedie MK, Yaeger DM. Drug Prescribing and its Relation to Length of Hospital Stay. Inquiry 17:254-259, 1980.
4. Soumerai SB, Avorn J. Predictors of Physician Prescribing Change in an Educational Experiment to Improve Medication Use. Medical Care 25:210-221, 1987.
5. Morrell J, Podlone M, Cohen SN. Receptivity of Physicians in a Teaching Hospital to a Computerized Drug Interaction Monitoring and Reporting System. Medical Care 15:68-78, 1977.
6. Cohen MR. A Compilation of Abstracts and Index of Articles published by the Boston Collaborative Drug Surveillance Program. Hospital Pharmacy 12:455-492, 1977.
7. Steel K, Gertman PM, Crescenzi C, Anderson J. Iatrogenic Illness on a General Medical Service at a University Hospital. N Engl J Med 304:638-642, 1981.
8. Kirking DM, Thomas JW, Ascione FJ, Boyd EL. Detecting and preventing adverse drug interactions: The potential contribution of comptuers in pharmacies. Soc Sci Med 22:1-8, 1986.
9. Rascati KL, Carole LK, Foley PT, Williams RB. Multidimensional work sampling to evaluate the effects of computerization in an outpatient pharmacy. Am J Hosp Pharm 44:2060-2076, 1987.
10. Pryor TA, Gardner RM, Clayton PD, Warner HR. The HELP System. J Med Systems 7:87-102, 1983.
11. Pryor TA. The HELP Medical Record System. MD Computing 5:22-33, 1988.
12. Lundsgaarde HP, Gardner RM, Menlove RL. Using Attitudinal Questionnaires to Achieve Benefits Optimization. SCAMC 13:703-708, 1989.
13. Weinstein MC, Stason WB. Foundations of Cost-Effective Analysis for Health and Medical Practices, N Engl J Med 296:716-726, 1977.
14. Linstone HA The Delphi Method Techniques and Applications, Murray Turoff Editors. Addison-Wesley Publishing Company, Reading, Massachusetts, 1975.
15. Sackman H. Delphi Critique. Lexington Book D.C. Heath and Company, Lexington, Massachusetts, 1975.
16. Bradshaw KE, Gardner RM, Pryor TA. Development of a Computerized Laboratory Alerting System. Comp Biomed Res 22:575-587, 1989.
17. Evans RS, Larsen RA, Burke JP, Gardner RM, Meier FA, Jacobson JA, Conti MT, Jacobson JA, Hulse RK. Computer surveillance of hospital-acquired infections and antibiotic use. JAMA 256:1007-1011, 1986.
18. Larsen RA, Evans RS, Burke JP, Pestotnik SL, Gardner RM, Classen DC. Improved perioperative antibiotic use and reduced surgical wound infections through use of computer decision analysis. Infect Control Hosp Epidemiol 10:316-320, 1989.
19. Pestotnik SL, Evans RS, Burke JP, Gardner RM, Classen DC. Therapeutic Antibiotic Monitoring: Surveillance Using a Computerized Expert System. Am J Med 88:43-48, 1990.
20. Tierney WM, Miller ME, McDonald CJ. The Effect on Ordering of Informing Physicians of the Charges for Outpatient Diagnostic Tests. N Engl J Med 322:1499-1504, 1990.
21. Shortliffe EH. Computer Programs to Support Clinical Decision-Making. JAMA 258:61-66, 1987.
22. McDonald CJ, Tierney WM. Computer-stored Medical Records: Their Future Role in Medical Practice. JAMA 259:3433-3440, 1988.
23. Couch NP, Tilney NL, Rayner AA, Moore FD. The High Cost of Low-Frequency Events - The Anatomy and Economics of Surgical Mishaps. N Eng J Med 304:634-637, 1981.

Supported in Part by Public Health Service Grants HS-02463 and HS-01053.