An Electronic Medical Record that Helps Care for Patients with HIV Infection

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We have built a clinical workstation to help doctors and nurses care for patients with HIV infection. This knowledge-based medical record system provides medication alerts, reminders about primary care, and on-line information to support the care of patients with HIV infection. We are conducting a controlled clinical trial of this computer system in a single practice setting, which consists of 18 staff physicians, 13 nurses, and 113 residents, who cooperatively practice in four teams. Two teams of physicians are assigned to an intervention group and two teams to a control group. This paper reports preliminary results from the first year of study, January 15, 1992, through January 14, 1993. During this period 274 patients with HIV infection were followed by the general medical practice —130 in a control group and 144 in an intervention group. Physicians in the intervention group more rapidly and more completely followed primary care guidelines than did physicians in the control group. Patients in the intervention group had 2476 ambulatory or emergency visits (17.2 visits per patient) compared with 1882 visits (14.5 visits per patient) for the control patients ($p<0.01$). There were 101 hospitalizations for 51 patients in the intervention group (an admission rate of 0.7) compared with 104 admissions for 54 patients in the control group (an admission rate of 0.8) (p=NS). There were 8 deaths in the intervention group (5.6%) compared with 13 (10%) in the control group (p=NS). Our intervention is associated with more complete documentation, more frequent primary care interventions, more ambulatory care, but no difference in total health care costs.

INTRODUCTION

Between 1 million and 2 million persons in the United States are estimated to be infected with human immunodeficiency virus (HIV). The enormous dimensions of this problem are causing a shift in the demographics of health care for persons with HIV infection — from infectious disease specialists to primary care physicians and from academic medical centers to community practices. However, the general internist needs help because of the complexity of the care and the rapidly changing nature of diagnosis and treatment. The need is for timely, accurate information *at the point of delivery of patient care.*

A computer system is an excellent vehicle to respond to this pressing need for information. Work by Bleich and Slack at Beth Israel and Brigham and Women's hospitals in Boston [1-3], McDonald at the Regenstrief Institute in Indianapolis [4,5],Warner, Pryor, and Clayton at LDS Hospital in Salt Lake City [6,7], Hammond and Stead at Duke University [8], Barnett at the Massachusetts General Hospital in Boston [9], and Simborg and Whiting-O'Keefe at the San Francisco Medical Center [10] has shown that computer systems can be integral parts of the health care system. When well designed, they will be heavily used by physicians and nurses, and can have a positive impact on the care of patients [11-18].

Clinicians faced with the increasingly complex burden of caring for patients with HIV infection must turn to patient-centered information infrastructure for help. Computer systems, like the T-HELLPER system being developed by Musen and colleagues, will help identify which patients could benefit from being enrolled in research protocols [24]. Computer systems and their associated databases, such as the ATHOS being developed by Fries and McSchane, will help structure this information for epidemiological monitoring and research [25]. We have developed a computer system that is designed to help the primary care physician keep up with the changing and challenging treatment needs of patients with HIV infection. We report preliminary data from a controlled clinical trial designed to measure the effect, if any, on patient care.

METHODS

Study Site

Boston's Beth Israel Hospital is a 504-bed major teaching hospital that is served by the Center for Clinical Computing (CCC) system, a mature clinical computing system that has been in evolution for more than a decade. This system has been extensively described in the literature [1-3]. From any of the 1500 terminals throughout the hospital, clinicians electively use this system over 50,000 times per week to look up information about the patients they are caring for, to send and receive over 14,000 pieces of electronic mail each week, and to perform over 1200 MEDLINE literature searches via PaperChase.

The Outpatient Medical Record

We have developed, as part of the CCC system, an electronic medical record system for ambulatory care, which we call the Outpatient Medical Record (OMR) system [19,20]. This system allows the clinicians in Healthcare Associates, the primary care medical practice at Beth Israel Hospital, to keep a paperless record.

OMR has been designed around three general principles — 1) the clinician should frequently interact with the system, 2) there should be no transcription from paper forms, and 3) data entry should be kept to a minimum and shared among clinicians and others on the hospital's staff. Having clinicians interact directly with the computer system increases the accuracy of data capture and, more important, dialogue with the computer system provides an opportunity for education, documentation, and action. It is this opportunity that will allow us to effect changes in practice guidelines and to disseminate this information. A detailed description of the OMR system has been published [19,20].

Knowledge-Based Medical Records

Building upon the working infrastructure of the OMR system and the CCC system, we have developed and are testing a knowledge-based medical record (KBMR-HIV) designed to help primary care clinicians care for patients with HIV-related illness [19]. Briefly, this system consists of 1) a mechanism for identifying and tracking patients with HIV infection, 2) rules for the primary care of patients with HIV infection, 3) methods for delivering suggestions about care, methods to help carry out these suggestions, and methods to document these actions, 4) interactive surveys to collect data from clinicians, and 5) on-line information (including full-text journals and texts) to support the care of patients with HIV infection.

We developed computer programs ***to alert or remind*** the clinician about these clinical events, to help the clinician ***to act*** on the information, and ***to document*** the clinician's response in the medical record. We call a rule an alert if the rule calls for urgent attention (e.g., "your patient's white blood cell count has dropped and you should consider adjusting the AZT dose" or "your patient's CD4 count has been below 200 on two occasions and you should consider prophylaxis for *Pneumocystis carinii* pneumonia"). We call a rule a reminder if the information can wait until the next scheduled visit (e.g., "your patient needs an influenza vaccination"). If alerts are pending, the clinician is informed every time the main options are displayed: "You have MEDICAL ALERTS." In addition to providing timely information, the HIV alerts are designed to help the clinician carry out the intended action. For instance, when the clinician is told that an AZT dose should be modified, seven choices are offered: 1) modify the dose, 2) indicate that the alert is inappropriate or inapplicable, 3) indicate that the alert was sent to the wrong person, 4) forward the alert to a specific person, 5) calendar the alert until the next appointment, 6) display the on-line medical record, or 7) display test results. If the clinician chooses "modify the dose," the computer offers to print a new prescription, send a letter to the patient, or schedule an appointment with the patient. The patient's telephone number is also prominently displayed. As a byproduct of delivering a rule on the computer and assisting in an action to carry out the rule (e.g., actually order the test, print the prescription, gather the data), documentation is created in the electronic medical record. This helps create not only well-documented individual care, but also a standardized database for practice monitoring. Reminders look exactly like alerts, but are presented only at the time of a patient visit.

Study Design

The KBMR-HIV system was implemented on January 15, 1992, and a controlled clinical trial was begun on that date. Our study design was to find the pairing of teams that best controlled for practice variation. One pair of teams would be the intervention group, and one pair of teams the control group. Both teams of clinicians use the OMR system. Both teams of clinicians have access to the four new HIV data forms (HIV primary care screening; CD4 flow sheets; review-of-symptoms checklist; and the baseline/follow-up data form. The clinicians on the intervention teams receive medical alerts for their patients. Reminders are posted for all patients the night before a scheduled clinic appointment. Clinicians in the intervention groups can view these reminders; clinicians in the control groups are blinded to the existence of reminders. Study clinicians can document appropriate entries on the screening sheets in response to reminders. Control clinicians must directly enter the HIV screening sheet to document care. All providers are reminded to complete the review-of-symptoms checklist. The information resources other than HIV ProtoCall, which all providers can see, are available only to the intervention group. All providers receive electronic surveys periodically.

To compare the groups, we use standard statistical methods for the analysis of incomplete time-to-event data. The data are incomplete in the sense that some of the reminders generated have not yet been fulfilled, so we know that the time to fulfillment is longer than the observation time, but we do not know exactly how much longer. Distributions of time to documentation are estimated by the product limit method of Kaplan and Meier [22]. Comparisons between groups are made using the log rank test [23]. Values are presented $\pm$ SD.

RESULTS

Study Population

At the end of the study year, there were 544 patients in the Healthcare Associates (HCA) HIV database. Fifteen patients did not have any primary care provider assigned in the computer database. Alerts were potentially sent to both the primary care physician and the primary care nurse. For a small number of patients (n=56), their primary care physician and primary care nurse were on opposite sides of the study, or the primary care physician switched teams during the study. These 56 patients were excluded. Finally, 88 patients were cared for by the co-investigators and were excluded. Thus, 385 patients with HIV infection were in the HCA database. Of these patients, only 274 actually had scheduled visits in HCA during the year study period. The following preliminary analysis will be restricted to the 274 patients who were seen in a primary care setting during the first year of study.

Demographics and Visit History

In the control group, 130 patients had a total of 889 HCA visits and were cared for by 73 different clinicians (9 staff physicians, 5 fellows, 53 resident physicians, and 6 nurses). In the intervention group, 144 patients had a total of 1101 HCA visits and were cared for by 71 clinicians (9 staff physicians, 4 fellows, 51 resident physicians, and 7 nurses).

Patient demographics were similar in the control and intervention groups. Patients' initial CD4, defined as a CD4 two weeks prior to entry into our study, the first CD4 in the month following entry, or the last CD4 in the six months prior to entry in the study, was 372$\pm$278 (mean$\pm$SD) in the control group and 340$\pm$269 (p=NS) in the intervention group. The 144 patients followed by the intervention group had more HCA visits with staff physicians and incurred higher per patient HCA charges (713\pm$523) than the 130 patients followed by control group (653\pm$651) (p=NS). The patients in the intervention group had more visits to medical subspecialists, respiratory therapists, and ophthalmologists. Consequently, these 144 patients had higher non-HCA charges per patient as well (970\pm$1,210) compared to ($624$\pm$875) (p = 0.01). Overall patients in the intervention group had 2476 ambulatory or emergency visits (17.2 visits per patient) compared with 1882 visits (14.5 visits per patient) for the control patients ($p<0.01$).

There were 101 hospitalizations among 51 patients in the intervention group (an admission rate of 0.7) compared with 104 admission among 54 patients in the control group (an admission rate of 0.8) (p=NS). Finally, the control group had 13 deaths with a crude mortality rate of 10%, while the intervention group had only 8 deaths with a 5.6% mortality (p=NS). Mean charges for hospitalizations were $12,300$\pm$28,496 for the 130 patients in the control group and $11,797$\pm$25,529 for the 144 patients in the intervention group (p=NS). Overall total mean charges for inpatient and ambulatory care were $13,576$\pm$28,946 for the 130 patients in the control group and $13,481$\pm$25,795 for the 144 patients in the intervention group (p=NS).

Analysis of Reminders and Alerts

One of our primary concerns is how to evaluate the impact of the alerts and reminders on the behavior of the care providers, i.e., to determin whether there is any measurable change in the provision of care. One approach to this is to measure the time required to comply with a practice guideline. Specifically, in the context of our trial we compared the time from the generation of an alert or reminder until the recommended action was taken for patients in the intervention and control groups.

Alerts were potentially sent to both the primary care physician and the primary care nurse. Eighteen percent of all alerts were marked in the intervention group as inappropriate, and 9% were sent to the wrong provider. Alerts were judged inappropriate if the patient was no longer taking a medication, if the patient had laboratory testing done outside our hospital and the results were not known by the computer system, if the patient refused, or if the physician overrode the alert. These alerts were not removed from analysis, however, because the control group did not have an opportunity to respond similarly.

During the first year of study, 230 alerts were delivered to clinicians in the intervention group and 202 alerts were generated, but not delivered by the computer, for patients followed by clinicians in the control group. During the same period of time, 712 reminders were delivered to clinicians in the intervention group and 606 reminders were generated, but not delivered by the computer, for patients followed by clinicians in the control group.

Table 1 shows the estimated median time to documentation and the results of the log rank tests for each of the alerts and reminders. The data used to derive this table can be graphically represented for each alert or reminder as shown in Figure 1.

Table 1. Median Time to Documentation
(weeks)

	Intervention	Control	p-value
Reminders			
Baseline labs	5	>52	0.0008
H. Inf vaccination	40	>52	<0.0001
Ophthalmology exam	21	>52	0.0001
PAP	9	43	0.0104
Pneumovax	15	>52	<0.0001
PPD	19	>52	<0.0001
Tetanus	>52	>52	ns
Alerts			
Begin AZT	16	13	ns
Order CBC	3	4	ns
Order CD4	11	11	ns
Adjust AZT Dose	11	4	0.0356
PCP Prophylaxis	27	41	ns

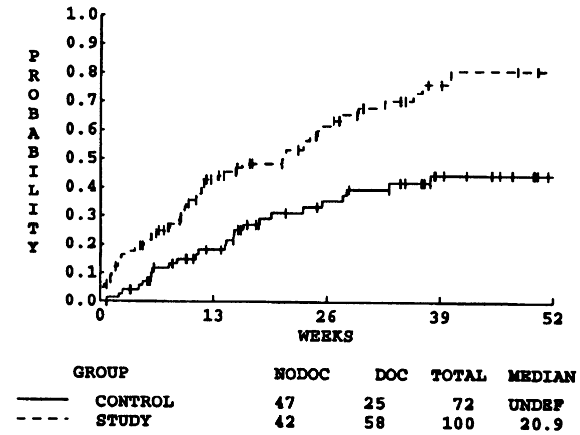

Figure 1. Kaplan-Meier curves showing the time to document primary care interventions

We interpret these results to indicate that these computer-generated reminders are very effective but that no difference can be shown for the more urgent medication-related alerts. In the specific cases of reminders for Pap smears, baseline laboratory testing, and ophthalmology screening, the time to documentation reflects the time to intervention because facts about these interventions are reflected in the CCC system.

DISCUSSION

We have shown that physicians who use our integrated clinical workstation while they care for patients with HIV infection provide more primary care than physicians who do not have this support. Clinicians in our intervention group are able to institute specific guidelines more than twice as rapidly and twice as completely the clinicians in the control group. Patients cared for by physicians in the intervention group have had more ambulatory visits, but no increase in total health care expenditures.

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