Special Article

A COMPUTERIZED REMINDER SYSTEM TO INCREASE THE USE OF PREVENTIVE CARE FOR HOSPITALIZED PATIENTS

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ABSTRACT

Background Although they are effective in outpatient settings, computerized reminders have not been proved to increase preventive care in inpatient settings.

Methods We conducted a randomized, controlled trial to determine the effects of computerized reminders on the rates at which four preventive therapies were ordered for inpatients. During an 18-month study period, a computerized system processed on-line information for all 6371 patients admitted to a general-medicine service (for a total of 10,065 hospitalizations), generating preventive care reminders as appropriate. Physicians who were in the intervention group viewed these reminders when they were using a computerized order-entry system for inpatients.

Results The reminder system identified 3416 patients (53.6 percent) as eligible for preventive measures that had not been ordered by the admitting physician. For patients with at least one indication, computerized reminders resulted in higher adjusted ordering rates for pneumococcal vaccination (35.8 percent of the patients in the intervention group vs. 0.8 percent of those in the control group, $P<0.001$), influenza vaccination (51.4 percent vs. 1.0 percent, $P<0.001$), prophylactic heparin (32.2 percent vs. 18.9 percent, $P<0.001$), and prophylactic aspirin at discharge (36.4 percent vs. 27.6 percent, $P<0.001$).

Conclusions A majority of hospitalized patients in this study were eligible for preventive measures, and computerized reminders significantly increased the rate of delivery of such therapies. (N Engl J Med 2001; 345:965-70.)

ALTHOUGH they are cost effective, preventive care measures are underutilized. Pneumococcal vaccination is associated with decreased rates of hospitalization, decreased rates of bacteremia, and cost savings among patients who are at least 65 years old,[1-3] yet the vaccine is administered to only 45 percent of such patients.[4] Similarly, only 66 percent of patients in this age group are vaccinated against influenza,[4] despite reports that vaccination leads to decreased mortality, hospitalization rates, and medical costs.[5-7] Daily aspirin use reduces the risk of myocardial infarction, stroke, and death in persons who are at high risk for occlusive vascular disease,[8] yet 22 percent of eligible patients may leave the hospital after acute myocardial infarction without an order for aspirin.[9] Similarly, the prophylactic use of subcutaneous heparin reduces the incidence of venous thromboembolism among hospitalized patients with various medical conditions,[10] but only one third of such high-risk patients receive this treatment.[11,12]

Although multiple randomized trials have confirmed that computerized reminders increase the use of preventive care in the outpatient setting,[13-17] a trial among hospitalized patients failed to demonstrate an increase in the use of preventive care measures with this intervention.[14,18] Nevertheless, hospitalization represents an opportunity to target persons who are particularly likely to benefit from preventive care. For example, 1 future hospitalization might be avoided by the simple administration of pneumococcal vaccine to 100 appropriate hospitalized patients.[19] We hypothesized that a computerized reminder system could increase the use of preventive care among hospitalized patients.

METHODS

Setting and Eligibility

We obtained approval for this study from the institutional review board of the Indiana University Medical Center. The board did not require informed consent from patients, since computer reminders have been considered routine components of care in the outpatient setting. We included all patients admitted to the general-medicine service of Wishard Memorial Hospital, an urban public teaching hospital in Indianapolis, between May 1, 1997, and October 31, 1998. The organization of the teams of the general-medicine ward has been described previously[18]; at present there are eight independent teams whose staff members (physicians and students) rotate approximately monthly.

Randomization and Outcomes

Using a blinded system of coin randomization, one of the investigators randomly designated four of the general-medicine teams

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as intervention teams and four as control teams. All physicians, medical students, and patients associated with a team were assigned that team's intervention status. The same investigator also randomly assigned physicians to teams insofar as practical constraints allowed (e.g., avoiding assignments that might lead to two consecutive nights of overnight on-call duty). When physicians returned for multiple rotations during the study period, we attempted to maintain their original intervention status by assigning them to teams with the same status; most medical students had only one rotation at the hospital during the study period. Patients were admitted to the general-medicine wards with the use of a system that distributed admissions equally among the teams, solely on the basis of the order in which patients required hospitalization. Patients automatically assumed the intervention status of the team to which they were assigned on admission and retained that status for the duration of their hospitalization. Previous studies involving inpatients have shown no material differences in clinical status among patients assigned to different teams.[20]

The primary outcomes of interest were the rates at which the various preventive therapies were ordered. These rates were obtained from routinely stored data.

Computerized Order Entry and Clinical-Decision Support

Using personal-computer–based order-entry workstations,[18,20-22] resident physicians and medical students on the general-medicine teams wrote all orders (except for do-not-resuscitate orders); these persons were the targets of the intervention. During the order-entry process, the system provided clinical-decision support to physicians and medical students by means of rule-based reminders, which we called Care rules.[18,23] The Care rules generated the reminders in this study as prewritten orders with explanatory text. Physicians could accept or reject the reminders with one or two keystrokes on the computer.

Generation and Display of Computer Reminders

Using the Care rules, we implemented national guidelines that were current at the time of the study regarding the use of pneumococcal vaccination,[3] influenza vaccination,[24] prophylactic enteric-coated aspirin for cardiovascular disease,[25-27] and prophylactic subcutaneous heparin to reduce the risk of thromboembolic events in patients with certain medical conditions.[28] Computer-generated reminders for all but one of these therapies (subcutaneous heparin) have been a routine part of care in the outpatient setting for more than 15 years. The computer was programmed to suggest influenza vaccination only during the "flu-shot season" from October 1, 1997, through January 31, 1998. Before the study, we tested the appropriateness of the reminders generated by the Care rules (available from NAPS*) by having the practitioners review the rules directly to judge whether they were reasonable and by running the rule-based reminder program on a sample of more than 300 patient records and manually validating the recommendations by reference to the rules and the content of the computerized medical charts.

The Care rules relied on multiple sources of such routinely collected data as demographic characteristics of the patient, lists of medical problems, diagnoses at previous hospital discharge, vital signs, active inpatient orders, previous pharmacy records, and coded radiologic results. In addition, we obtained information from patients on their vaccination status by means of a standard admission questionnaire completed by a research assistant or the admitting nurse. The Care rules generated reminders when the patient's electronic medical record included at least one indication for one of the selected preventive therapies, no evident contraindication to the therapy, no active orders for the therapy, and in the case of the two vaccinations, no record of previous administration within an appropriate time frame.

*See NAPS document no. 05605 for 8 pages of supplementary material. To order, contact NAPS, c/o Microfiche Publications, 248 Hempstead Tpke., West Hempstead, NY 11552.

The Care rules program was used for all study patients (in both the intervention group and the control group) when the physician initiated an order-entry session for daily care, for the transfer of the patient, or for discharge. The program was not run and no reminders were generated when orders were entered at the time of admission; thus, the clinician had one opportunity to order the preventive therapies without receiving a reminder. The computer program logged the following types of data: the names of all the Care rules that were applied, all the resultant messages and orders that were generated, the dates and times of all messages and orders, the physician's identification number and intervention status, and the patient's hospital identification number and intervention status.

In most cases, the physician and the patient had the same intervention status; when physicians were on call or during emergencies, they might write orders for a patient with a different intervention status. When the physician and the patient were both assigned to the intervention group, the computer displayed to the physician all reminders generated by the program. When either the physician or the patient was assigned to the control group, the computer logged the reminders but did not display them. Patients whose data triggered a reminder were considered to be eligible for the specified therapy.

A sample computerized reminder message, as it would appear to a physician assigned to the intervention group, is shown in Figure 1. Physicians indicated their acceptance or rejection of each recommended therapy by choosing "order" or "omit." For the three therapies with few risks (influenza vaccination, pneumococcal vaccination, and subcutaneous heparin), we set the default to "order," so that the physician could accept the item simply by pressing the "enter" key. In the case of daily aspirin prophylaxis against coronary artery disease, we set the default to "omit," thereby requiring a more deliberate effort by the physician to change the status to "order." As a means of capturing the physician's attention briefly, we disabled the "escape" key and presented the reminders in a color scheme different from that used for physician-initiated orders. If a physician ordered the targeted therapy, no more reminders related to that therapy appeared. No reminders were displayed between the fifth hospital day and the time discharge orders were entered, at which time vaccination and prophylactic daily aspirin were suggested again if they were indicated.

Statistical Analysis

We compared the demographic characteristics of the patients in the intervention and control groups by means of the chi-square test and Student's t-test. The demographic data, including race, used for these comparisons were obtained as part of the routine procedures for hospital registration. The unit of analysis for all models was the individual hospital admission. We used a generalized-estimating-equation method[29] for all estimates of effect. We used a compound-symmetry structure, which assumes that patients are independent of each other and that hospitalizations for a particular patient have a fixed correlation that does not vary over time. Our primary analyses included all hospital admissions, but we also performed analyses that dealt with the effects of crossover by excluding patients and physicians who were part of both the intervention and the control group at different times. We limited these analyses to patients' first hospitalizations during the study period and excluded physicians who were in both the intervention group and the control group during the course of the study.

We modeled the effect of the explanatory variables (intervention status and demographic characteristics) on the binary response variable (therapy ordered or not ordered) with the use of logistic regression, and we considered a P value of 0.05 or less to indicate statistical significance. To account for possible similarities among the ordering rates of physicians working on the same team, we included in the models a variable indicating medical team nested within the intervention status. We created two models for each of the four preventive therapies — one including only the hospitalizations during which a reminder was generated by the computer, and the other including all hospitalizations.

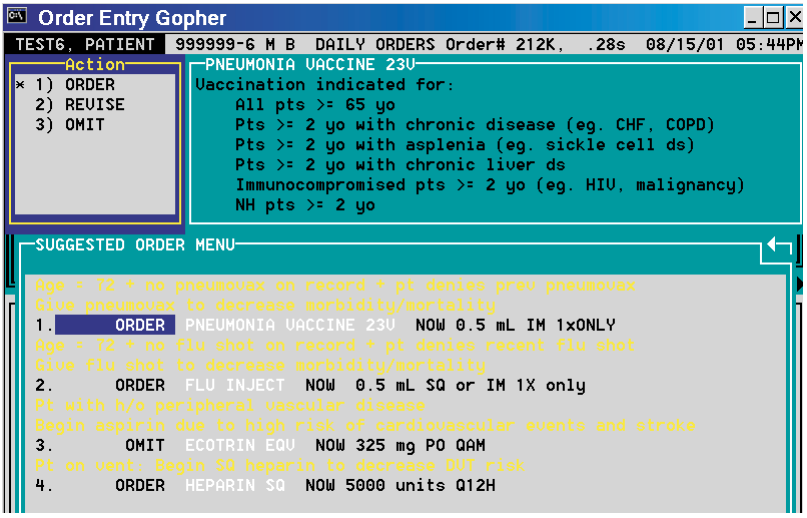

Figure 1. Example of a Computerized Reminder as Displayed to Physicians on Intervention Teams.

RESULTS

Study Subjects

A total of 6371 patients accounted for 10,065 admissions during the study period; patients were assigned to intervention teams for 4995 hospitalizations and to control teams for 5070 hospitalizations. Twenty-eight percent of the patients were hospitalized more than once. The mean age of the hospitalized patients was 53.2 years, 50 percent were women, and 51 percent were black. There were no significant differences in mean age, race, or sex between the intervention and control groups.

During the 18 months of the study, a total of 202 physicians rotated an average of 2.1 times onto the inpatient service: 96 of these physicians (47.5 percent) were assigned only to intervention teams, 78 (38.6 percent) were assigned only to control teams, and 28 (13.9 percent) were assigned at different times to intervention teams and control teams.

Computer Reminders and Ordering Rates for Preventive Therapies

Overall, 3416 patients (53.6 percent) were eligible for at least one preventive therapy. The mean number of times that a reminder was displayed to a physician on an intervention team ranged from 3.4 to 5.2 for each hospitalization of an eligible patient in the intervention group.

The display of computer-generated reminders had a significant effect on the use of each of the four preventive therapies (Table 1). The use of the reminders led to a higher ordering rate for pneumococcal vaccination (35.8 percent among eligible patients in the intervention group, as compared with 0.8 percent among eligible patients in the control group) and a higher ordering rate for influenza vaccination (51.4 percent as compared with 1.0 percent) (Table 1). When the total number of hospitalizations was used as the denominator for calculating the ordering rates for each of the preventive therapies, the rates were also significantly higher among patients in the intervention group than among those in the control group (Table 2). There were no important differences in our results when we limited our analyses to the patients' first hospitalizations and excluded the physicians who took part in both intervention and control teams during the study period.

Physicians varied in the frequency with which they accepted these reminders. The distribution of ordering rates among 114 physicians randomly assigned to the intervention group who received computerized reminders for at least 10 patients (range, 10 to 82) is shown in Figure 2.

The rates of physicians' orders for each of the four preventive therapies were positively correlated with the age of the patients ($P<0.002$ for all comparisons). Physicians also ordered prophylactic aspirin at the time of discharge more frequently for patients who were hospitalized for acute myocardial infarction and unstable angina than for those with other indications (cerebrovascular disease, peripheral vascular disease, and coronary risk factors) ($P<0.001$ for all comparisons).

DISCUSSION

The results of this trial provide compelling evidence that computerized reminders can increase the delivery of preventive care to hospitalized patients. For all four preventive therapies, the use of computerized reminders resulted in absolute ordering rates for both eligi-

TABLE 1. ADJUSTED ORDERING RATES FOR PREVENTIVE THERAPIES FOR ELIGIBLE PATIENTS.*

THERAPY	NO. OF ELIGIBLE PATIENTS (% OF ALL PATIENTS)	NO. OF HOSPITALIZATIONS OF ELIGIBLE PATIENTS (% OF ALL HOSPITALIZATIONS)	PERCENTAGE OF HOSPITALIZATIONS DURING WHICH THERAPY WAS ORDERED FOR AN ELIGIBLE PATIENT		P VALUE
			INTERVENTION GROUP	CONTROL GROUP	
Pneumococcal vaccination	1696 (26.6)	2314 (23.0)	35.8	0.8	<0.001
Influenza vaccination	1033 (16.2)	1251 (12.4)	51.4	1.0	<0.001
Subcutaneous heparin	1083 (17.0)	1326 (13.2)	32.2	18.9	<0.001
Aspirin at discharge	1698 (26.7)	2240 (22.3)	36.4	27.6	<0.001

*There were a total of 6371 patients and a total of 10,065 hospitalizations; patients were assigned to intervention teams for 4995 hospitalizations and to control teams for 5070 hospitalizations.

TABLE 2. ADJUSTED ORDERING RATES FOR PREVENTIVE THERAPIES FOR ALL 6371 HOSPITALIZED PATIENTS DURING 10,065 HOSPITALIZATIONS.

THERAPY	PERCENTAGE OF HOSPITALIZATIONS WITH AN ORDER FOR THERAPY		P VALUE
	INTERVENTION GROUP	CONTROL GROUP	
Pneumococcal vaccination	8.5	0.9	<0.001
Influenza vaccination	5.4	0.4	<0.001
Subcutaneous heparin	10.5	8.2	<0.001
Aspirin at discharge	29.7	25.4	0.005

ble patients and all hospitalized patients that were significantly higher than the rates in the control group. In particular, the use of reminders increased the use of pneumococcal and influenza vaccination from practically zero to approximately 35 percent and 50 percent, respectively. (Analyses of data from the 15 months after the completion of the controlled trial revealed that, with continuing reminders, these rates had increased to 50 percent for pneumococcal vaccination and 57 percent for influenza vaccination.) The easy sustainability of computer-based reminder systems contrasts with the weaknesses of such approaches as manual reviewing of charts,[30,31] patient-directed interventions,[32,33] and physician-directed continuing medical education.[30]

Previous studies of computer-generated reminders for preventive care have focused almost exclusively on the outpatient setting.[14] Yet we found that 54 percent of patients hospitalized in general-medicine wards were eligible for preventive care interventions and that physicians' rates of compliance with the reminders were similar to those achieved in outpatient settings.[15] These findings alone would justify focusing greater attention on preventive care for inpatients, but there are other reasons to do so as well. For one, patients hospitalized because of severe underlying diseases may benefit more from preventive measures (e.g., pneumococcal vaccination[19,34]) than patients who do not require hospitalization. Also, among patients who do not have regular outpatient follow-up, hospitalization may offer the only good case-finding opportunity to provide such care.[35] Other preventive therapies, such as subcutaneous heparin, are specifically indicated in the hospital setting.

The findings of this study contrast with the results of a previous study performed at our institution that did not demonstrate an effect of computerized reminders.[18] We attribute our recent success to relatively small changes in the presentation of these reminders. In our previous study, we relied on physicians to make a deliberate choice to view the reminders and notified them only by means of a banner at the bottom of the screen stating that "there are suggested orders for this patient." By contrast, in the current study, the computer immediately displayed the reminders to the physicians as full, prewritten orders. In this study, we also highlighted the suggested reminders with a distinctive color scheme, disabled the "escape" key, repeated the individual reminders approximately four times per hospitalization, on average, and set the default to "order" for three of the preventive therapies (allowing the physician to accept the item simply by pressing the "enter" key).

We do not have data on the reasons for noncompliance by physicians in the intervention group. In some cases, physicians may have had good reasons for ignoring a reminder; they may have known something that the computer did not — for example, the patient may have told the physician that aspirin had caused bleeding in the past. Furthermore, the compliance rates of physicians in some cases were related to the strength of the indication. For example, physicians complied with reminders for aspirin prophylaxis in 79 percent of the

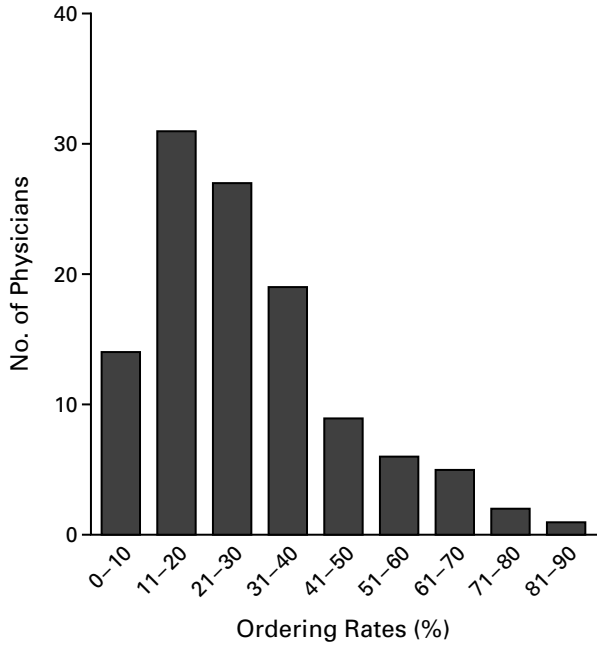

Figure 2. Distribution of Ordering Rates for Preventive Therapies among the Physicians in the Intervention Group.

Data are limited to the physicians who had at least 10 patients for whom reminders were displayed.

cases in which a patient was admitted for an acute myocardial infarction but only 22 percent of the cases in which indications were an age of more than 50 years and two or more coronary risk factors.

As in previous studies,[36] there was a great deal of individual variation among physicians in their acceptance of the reminders. This variation suggests that some portion of the overall rate of noncompliance was attributable to very low compliance among some physicians who generally ignored the reminders. The extremely low rate of use of vaccinations in the control group also suggests that some of the noncompliance with vaccination reminders could be attributed to long-established habits of vaccinating patients only in the outpatient setting.

Although the reminders in this study were based on a physician order-entry system and a rich repository of clinical data, neither of these features is necessarily a prerequisite to improving hospital-based preventive care. In the outpatient setting, reminders written on paper encounter forms are effective in increasing the use of preventive care.[16] The daily patient census reports produced for physicians in many hospitals could be as effective a mechanism for delivering reminders in the hospital as an order-entry system. Furthermore, the majority of the reminders generated in our study were triggered by information that is routinely available in hospital information systems. For example, an age of at least 65 years is a valid indication for pneumoccal and influenza vaccination. The addition of the diagnosis on admission, past diagnoses, and the service to which the patient was admitted would have been sufficient to identify the majority of patients with indications for vaccinations and many of those with indications for aspirin or subcutaneous heparin. It is likely that with a small amount of computer programming and the creation of nursing or other protocols to check for possible contraindications and previous vaccinations, many hospitals could implement programs that provide simple reminders and thereby improve preventive care for inpatients.

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