Research Paper ■

Computer-generated Informational Messages Directed to Physicians: Effect on Length of Hospital Stay

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Abstract **Objective:** With the advent of hospital payment by diagnosis-related group (DRG), length of stay (LOS) has become a major issue in hospital efforts to control costs. Because the Columbia-Presbyterian Medical Center (CPMC) has had above-average LOSs for many DRGs, the authors tested the hypothesis that a computer-generated informational message directed to physicians would shorten LOS.

Design: Randomized clinical trial with the patient as the unit of randomization.

Setting and Study Population: From June 1991 to April 1993, at CPMC in New York, 7,109 patient admissions were randomly assigned to an intervention (informational message) group and 6,990 to a control (no message) group.

Intervention: A message giving the average LOS for the patient's admission or provisional DRG, as assigned by hospital utilization review, and the current LOS, in days, was included in the main menu for review of test results in the hospital's clinical information system, available at all nursing stations in the hospital.

Main Outcome Measure: Hospital LOS.

Results: The median LOS for study patients was 7 days. After adjustment for covariates including age, sex, payor, patient care unit, and time trends, the mean LOS in the intervention group was 3.2% shorter than that in the control group ($p = 0.022$).

Conclusion: Computer-generated patient-specific LOS information directed to physicians was associated with a reduction in hospital LOS.

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The Tax Equity and Fiscal Responsibility Act (TEFRA) of 1982 converted Medicare reimbursement for hospital care to a prospective payment system based on diagnosis-related groups (DRGs), and many other payors soon followed suit.[1] Length of stay (LOS) per admission has subsequently become a major issue in hospital cost management, and hospitals now have major financial incentives to complete the diagnostic and therapeutic care of patients as quickly as possible within the limits of medical appropriateness. The mean LOS in U.S. hospitals has steadily declined since the introduction of prospective payment.[1,2] In our institution, mean LOS is higher than in comparable tertiary care hospitals nationally and within the New

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York area, even after case mix adjustment (R. Arons, unpublished data).

Many factors contribute to excessive LOS, and some of these factors cannot be influenced by physicians within the limits of good medical care. However, studies from other institutions indicate that computer-generated informational interventions directed at physicians can affect physician behavior. Tierney et al. at the Regenstrief Institute have published a series of controlled studies demonstrating that outpatient test ordering and costs were reduced when physicians were shown prior test results,[3] computer-generated predictions of abnormal results,[4] and test prices,[5] and that inpatient LOS, diagnostic test charges, pharmacy charges, and overall costs were all reduced through computer-generated feedback linked to computerized order entry.[6] Pugh et al. recently reported that daily charge feedback to physicians in an inpatient setting using a computer-generated sheet placed on the chart reduced total charges, diagnostic testing, and LOS.[7]

We therefore developed and evaluated a computer-generated informational message directed to physicians as an intervention to reduce LOS at our institution. Although the intervention had intuitive appeal, there are costs associated with ensuring that the correct or "working" provisional DRG is assigned to each patient early in his or her hospital stay. We evaluated the effectiveness of the intervention using a randomized controlled design.

Methods

Description of the Intervention

The Columbia-Presbyterian Medical Center Clinical Information System is a mainframe-based application. Users of the system logon to PCs attached to the institution-wide network and access the mainframe via 3270 terminal emulation. There is a front-end, PC-based script program that streamlines the logon and logout procedures.[8] To review diagnostic test results or other clinical data, the user first selects a patient. A list of clinical data types available for that patient is then displayed, and the user proceeds to review clinical results.

When a physician used the clinical information system to review test results for an intervention group study patient, the screen displayed the mean LOS for the patient's provisional DRG and the actual LOS for that patient (Fig. 1). A message indicated that more information could be obtained by pushing the "F5" key. This key brought up a screen showing the three leading diagnoses on which the provisional DRG was based and the names and telephone numbers of people to call regarding the correctness of these diagnoses and for help in facilitating discharge planning. An example of this screen is shown in Figure 2. Other than the computer-based messages, no educational intervention was directed to physicians regarding LOS issues, nor were the physicians told beforehand that messages would appear for some patients.

Name: SAMPLE, GEORGE A. Sex: F Birthdate: 06/06/944 MRN: 1234567

Selection Menu

Enter selection.....: 1

11/12/93	1. Laboratory	|	--	7. Ob/Gyn
11/10/93	2. Radiology	|	--	8. Head and Neck
11/03/93	3. Pathology	|	--	9. GI Endoscopy
--	4. Admit/Discharge Notes	|	11/09/93	10. Cardiology
--	5. Operative Reports	|	--	11. Clinical Profile
--	6. Neurophysiology	|	--	12. Computer Alerts

This patient has been in the hospital for....... 13 days (More info=F5)
Mean LOS for this patient's provisional DRG is.... 6 days (reviewed 11/10/993)

Figure 1 Main menu of the Columbia-Presbyterian Medical Center's clinical information system, showing the length-of-stay intervention message (bottom two lines of the screen). These two lines appeared only for patients randomized to the intervention group.

Mean LOS

The mean LOS message was derived from a table of target LOS values for Presbyterian Hospital calculated for 1991 by Dr. Arons (Director, Case Mix Studies, Presbyterian Hospital). This table was based in part on experience at New York Hospital during the previous year, where LOS had been substantially shorter than at Presbyterian Hospital. Studies comparing LOS at Presbyterian Hospital and New York Hospital indicated that although 58% of the excess days were in Medicare, 26% in Medicaid, and 16% in Blue Cross/commercial, the mean LOS differential was greatest among patients with Blue Cross and other commercial insurance. Therefore, the target LOS values used in our study were generally shorter for commercially insured patients than for patients whose primary payor was Medicare or Medicaid, within the same DRG. In a few DRGs, the differential in target LOS was as much as threefold compared with New York Hospital.

How LOS Data Were Obtained

Utilization review nurses reviewed the charts of all new admissions to the study floors within three days of admission, usually earlier, and assigned provisional diagnoses. These nurses were not aware of which group—intervention or control—the patients were assigned to in the study. Based on these diagnoses, a provisional DRG was also assigned, and from the DRG a target LOS was generated. It was recognized that the target LOS was not necessarily an appropriate LOS target for each diagnosis encompassed by a DRG or for each patient with a given diagnosis. However, we also felt that most physicians might not be aware of this information for their patients, and that it might be helpful to them in planning care for their patients. As mentioned, the Presbyterian Hospital's target LOS for a given DRG varied somewhat across third-party payors.

The provisional diagnoses were coded and entered into the computer using the 3 M Health Systems International Code 3 DRG Grouper application (3 M Health Information Systems, Wallingford, CT) running on the Data General computer (Data General Corporation, Westboro, MA) used by Medical Records. This application supports a program that assigns a provisional DRG. These data were uploaded from the Data General computer to the clinical information system running on an IBM mainframe computer (IBM Corporation, Armonk, NY), where a target LOS, specific to the patient's payor and based on the provisional DRG, was generated for each patient. The clinical information system includes the database and display programs whereby test results are shown to physicians. The display program was modified to show the LOS data and the diagnoses on which the DRG and LOS were based. This modified program was activated only for the intervention patients.

For all study patients, the actual LOS and final DRG were obtained after discharge, from the Medical Records discharge coding program, via a data pass-through from the hospital's admission-discharge-

Name: SAMPLE, GEORGE A. Sex: F Birthdate: 06/06/944 MRN: 1234567

Admission Date: 10/30/993
Est. Disch. Date: 11/06/993 (Based on mean LOS)

Date of last review: 11/10/993
Working DRG: SIMP PNEUM & PLEURISY 18+ W/O CC
Mean Length of Stay: 6

Working DX: Procedures:
PNEUMONIA, ORGANISM NOS

If you have questions regarding data in this display or need assistance
resolving scheduling or ancillary delays please call the UR Coordinator:
ELLEN SMITH ext. 76417
If you have a problem with a patient discharge plan please call:
Social Work Services ext. 62464

Figure 2 Second screen of the length-of-stay intervention message. This screen was accessed from the main menu (Fig. 1) by a single keystroke and was available only for patients randomized to the intervention group.

Table 1 ■

Mean Lengths of Stays (LOSs) [with Standard Deviations (SDs)] for the Intervention and Control Groups According to Payor*

	Intervention Group			Control Group		
Payor	Number of Admissions	Mean LOS	SD	Number of Admissions	Mean LOS	SD
Blue Cross	1,293	8.19	11.77	1,284	8.10	13.94
Other commercial	960	7.37	10.01	939	6.89	8.04
Medicaid	1,742	11.62	14.71	1,700	12.17	13.58
Medicare	2,558	11.18	14.98	2,507	11.61	18.36
Other	556	7.13	8.10	560	7.58	10.89
All payors	7,109	9.91	13.45	6,990	10.15	14.97

*The mean LOSs and SDs are expressed in units of hospital days and are untransformed and unadjusted for diagnosis-related group or other covariates.

transfer program. The actual LOS and final DRG were used in all statistical analyses.

Setting

The hospital's clinical information system displays laboratory and other test results for all hospitalized patients. Data are available at all nursing stations, as well as at other locations, to physicians who wish to query the system. Utilization statistics indicate that almost all housestaff use the system to obtain results. The proportion of attending physicians who use the system varies across services, with more than 80% of active attendings on the Medical Service and more than 70% of active attendings on the Neurology Service regularly using the system. Because of these high rates of utilization, and because excess LOS was concentrated in the Medicine and Neurology Services, one patient care unit on each of these services was originally selected as the setting in which to evaluate the intervention. After the first five weeks (as of August 1, 1991), the study was extended to all of the patient care units in the Medicine and Neurology Services.

Subjects

Patients discharged alive from these Medicine and Neurology floors (a total of eight patient care units) were eligible for the study. Patients who were transferred to other hospitals or discharged against medical advice were excluded. The study began on June 21, 1991, and ended with patients admitted on or before April 21, 1993.

Design of the Evaluation Study

Study patients were randomized to an intervention group or a control group based on whether the sum of the digits in the Medical Record number was even (intervention) or odd (control). Intervention patients had the messages displayed. No message was displayed for control patients. Patients in our hospital are cared for by a team consisting of housestaff and attending physicians. In the case of private patients, orders are generally written by housestaff but decisions about discharge are generally made by the private attending. In the case of ward service patients, decisions about discharge may be initiated by either housestaff or attendings and are generally based on consensus. Housestaff and ward service attendings rotate, so that teams are dynamic. Randomization of physicians or physician teams was therefore not feasible, and the same physicians cared for both groups of patients. All physicians caring for the patient were targeted by the message in that it appeared whenever they checked the clinical information system results reporting for that patient.

Statistical Methods

For all analyses, the unit of analysis was the discharge. There were 11,296 patients having a total of 14,099 discharges during the study period. Multiple discharges of the same patient were treated as independent observations in the analyses. Since randomization was performed at the patient level, different discharges of the same patient shared the same intervention group. To eliminate the effect of DRG on LOS, the derived variable

$$\text{adjusted } \ln(\text{LOS}) = \ln(\text{LOS}) - \text{DRG-mean}$$

was computed, where ln(LOS) is the natural logarithm of LOS in days and DRG-mean is the mean ln(LOS) for all patients having a given DRG. The logarithmic transformation was used so that the distribution of the response variable would better obey the assumptions necessary for parametric statistical analyses. Small deviations in natural logarithms can be interpreted as approximate relative changes (e.g., an average difference of 0.05 in ln(LOS) between two groups implies about a 5% change in average LOS). As a preliminary analysis, a simple additive model was used, in which ln(LOS) was represented as the sum of a DRG baseline plus an effect of type of payor plus an effect of the intervention.

For the final analysis, a more complex analysis of covariance (ANOCOVA) model was used to estimate the effects of the intervention. The ANOCOVA model compared ln(LOS) within 3,246 strata defined by all combinations of DRG (393 levels), payor (5 levels), and patient care unit (8 levels) having at least one observation. Possibly confounding covariates (age and sex of the patient, and secular time trends within each payor and patient care unit) were entered into the model before entering the primary covariate, a dummy variable equal to unity for intervention patients. Although 14,099 patient admissions were available (intervention: 7,109; control: 6,990) some were missing values for one or more covariates. Therefore, 14,088 patient admissions were included in the ANOCOVA. Estimates of the intervention effect and of interactions between the intervention and the covariates were computed. Because of the log transform of the response, estimated effects of intervention are interpreted as proportional changes in LOS.

Results

The median LOS of study patients was 7 days, while the 10th and 90th percentiles were 1 and 21 days, respectively. Mean age on admission was 55.6 years (SD = 18.1) among intervention patients and 55.8 years (SD = 18.1) among control patients. Of the intervention group, 51.5% were men, compared with 51.0% of the control group. Table 1 shows the difference in LOSs between the intervention and control groups expressed in units of hospital days, untransformed and unadjusted for DRG or other covariates. The overall difference between the groups was 0.24 days, with shorter stay in the intervention group.

Table 2 shows the results of the preliminary multivariate analysis of log-transformed LOS, adjusted for DRG and stratified by payor type. As can be seen from Table 2, there is much more variation across payors than across experimental groups within payors. The column of Table 2 labeled "comparison" shows the estimates of the effect of the intervention. Negative effects denote shorter LOS in the intervention group. These effect estimates are not simple subtractions of the mean adjusted ln(LOS) from the intervention and control group means; rather, they result from fitting the preliminary additive model involving DRG, payor, and intervention status. This analysis estimates the overall effect of intervention to be a 2.3% reduction in LOS, with a standard error of 1.3% (two-sided $p = 0.085$). When separate estimates were made of the effect within each payor type, only the effect on Medicaid patient-stays was significant at conventional levels (effect = −0.068, SE = 0.027, $p = 0.011$).

To increase the power of the analysis, a more sophisticated model with increased stratification and several covariates was fit (Table 3). Among the covariates, the effects of age, sex, age by sex interaction, separate quadratic time trends within each patient care unit, and separate linear time trends within each payor type were significant. No interaction of any covariate with intervention was statistically significant at conventional levels. As shown in the analysis of covariance in Table 3, a test of the interaction between intervention and payor was not significant ($F = 1.75$; df = 4, 10,814; $p = 0.136$). Therefore, the

Table 2 ■

Mean Lengths of Stay (LOSs) [with Standard Deviations (SDs)] for the Intervention and Control Groups Adjusted for Diagnosis-related Group and Stratified by Payor Type*

	Intervention Group			Control Group				
Payor	Number of Admissions	Mean LOS	SD	Number of Admissions	Mean LOS	SD	Comparison† (effect ± SE)	Two-sided p Value
Blue Cross	1,293	−0.141	0.772	1,284	−0.093	0.777	−0.047 ± 0.031	0.130
Other commercial	960	−0.190	0.742	939	−0.194	0.721	0.006 ± 0.036	0.873
Medicaid	1,742	0.043	0.748	1,700	0.112	0.736	−0.068 ± 0.027	0.011
Medicare	2,558	0.112	0.794	2,507	0.119	0.806	−0.008 ± 0.022	0.712
Other	556	−0.138	0.708	560	−0.187	0.732	0.059 ± 0.047	0.215
All payors	7,109	−0.011	0.775	6,990	0.012	0.778	−0.023 ± 0.013	0.085

*Mean LOSs and SDs are of deviations of ln(LOS) from diagnosis-related group–stratum means.

†Comparison effect is based on an analysis of variance model of the form ln(LOS) = DRG-mean + payor-effect + intervention-effect + error, where the intervention effect is allowed to differ by payor in the first five rows and is assumed to be equal for all payors in the last row.

best model did not include a term for the intervention * payor interaction and had 23 degrees of freedom. Within this model, the adjusted coefficient for the overall effect of the computer intervention was −0.033 (SE = 0.014, two-sided $p = 0.022$). This is interpreted as a 3.2% reduction in LOS [$(e^{-0.033} - 1) \times 100\% = -3.2\%$]. This 3.2% difference is the best estimate in the sense of having been calculated from the best fitting model taking all measured covariates into account, and is highly consistent with the intervention effect calculated from untransformed, unadjusted data (Table 1).

In subgroup analyses based on models fitted separately for each payor, the computed effect of the intervention on Medicaid patients was greatest, with a coefficient of −0.076 (SE = 0.029) or a 7.3% reduction in LOS. However, considering that the intervention * payor interaction itself was not significant, and that this stratum-specific effect was the largest of several examined, the variation in effect among payors may well have been a sampling fluctuation.

Comment

The main finding of this research is that a patient-specific computer-generated informational message giving the mean target LOS for a patient, based on that patient's provisional DRG assignment, was associated with a 3.2% reduction in mean LOS, after adjustment for covariates. This observation was made using a randomized design that minimized differences between the intervention and control groups. The economic implications of this reduction may be gauged by noting that our Medical Service discharges approximately 5,000 patients per year, and the mean payment per discharge is approximately $10,000, representing approximately $50 million in total revenue. If the costs are assumed to be equal to payments, a 3.2% LOS reduction represents a reduction of $1.6 million in variable costs for the Medical Service alone. While it may be argued that costs are not equal to payments and that the true variable cost reduction is not as great as the proportional reduction in LOS, our Medical Service runs at full capacity for much of the year, so that earlier discharge translates directly into the admission of more patients and the generation of incremental revenue and/or contributions to margin. Thus, the financial value of LOS reduction to the hospital was substantial.

Our setting may differ from other hospitals in that our mean LOS is high compared with that of other hospitals, including other teaching hospitals in our geographic area. In hospitals where LOS has already been reduced, a similar reduction would not be expected from an intervention like the one we tested. Our study was conducted on the Medicine and Neurology Services, where many chronically ill patients with multiple problems receive care. The LOS reduction may not generalize to other services in which procedural or surgical care is provided, admissions are more often elective, or patients are younger and less likely to be chronically ill. Nonetheless, national trends in reducing LOS have not been confined to medical patients and have also been seen for DRGs such as uncomplicated delivery of normal newborn.

Table 3 ■

Results of an Analysis of Covariance of Length of Stay (LOS) Adjusted for Diagnosis-related Group (DRG) When Terms are Entered in the Order Indicated*

Source	DF	% Variance Explained	F Ratio	Pr > F
Between DRGs	392	42.5965	29.33	<0.0001
Payor, patient care unit within DRG	2,853	16.7634	1.59	<0.0001
Covariates	23	0.5261	6.17	<0.0001
Intervention	1	0.0193	5.22	0.0223
Intervention * payor	4	0.0259	1.75	0.1365
Error	10,814	40.0688		
Total	14,087	100.0000		
Dependent variables: ln(LOS)				
Root MSE: 0.740				

*All F ratios use error as the denominator.

The design of our study randomized patients rather than physicians, even though physician behavior has generally been taken as the primary endpoint of randomized studies of computer-generated messages designed to improve clinical care.[3–7,9–12] Randomization of physicians was not feasible in our setting, and the primary endpoint of our study was a characteristic of patients (LOS). Thus, we believe that the study design was appropriate for the study question, and that the findings are interpretable even though the study was limited by the absence of questionnaire data directly describing physicians' perceptions of the intervention and how it affected their behavior. To the extent that there was contamination due to physicians having patients in both the intervention and control groups, this would have biased the effect size downward, so that the observed effect of 3.2% is a conservative estimate.

The finding that LOS information directed to physicians influenced LOS is consistent with the findings of studies of other computer-generated messages.[9,10] Other interventions that have been coupled to information that have been shown to influence physician behavior are monitoring with feedback[12] and financial incentives.[13] Tierney et al. in a recently reported randomized controlled study showed that computer-based order entry coupled to reminders that discouraged unnecessary testing reduced inpatient costs by 12.7%.[6] Two recent studies of computerized reminders for preventive care in the outpatient setting found that reminders improved compliance with preventive services recommendations.[14,15] In one of these studies, the intervention was computer-generated reminders alone,[14] while in the other study, physicians who were required to respond to the reminders were more in compliance than were physicians who received the reminders alone.[15]

It should be emphasized that many factors other than physician awareness and motivation influence the LOS. In one recent study of causes of delays in discharge from a teaching hospital, the most important factors were delays in scheduling diagnostic tests and unavailability of postdischarge facilities.[16] Physician decision making and delayed discharge planning were additional factors. Lack of social support systems and community resources may be of particular importance in our setting, where a large number of patients who have Medicaid or both Medicare and Medicaid[17] receive care. Physician payment, unlike hospital payment, remains based on per diem fee-for-service reimbursement for the great majority of nonsurgical patients in our setting. Physicians also wish to avoid conflict with their patients, who sometimes may feel they want to stay longer.[18]

The findings reported here add to a growing body of literature showing that computer-generated informational messages directed to physicians at the "point of service"—at the time when and in the place where clinical decisions are made—can improve the quality and efficiency of health care. These messages can be effective, even in the absence of educational efforts or other organizational changes, if the information they contain is credible and relevant to the care of specific patients.

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