Using A Hospital Information System To Assess The Effects Of Adverse Drug Events

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ABSTRACT

The most common adverse events experienced by hospitalized patients are drug related. While numerous studies have described the incidence and types of adverse drug events (ADEs), the actual effect of these events on patient outcomes have only been estimated. The studies that have described the effects of ADEs on patient outcomes have not stratified patients by severity of illness and hospital costs were estimated based on a percent of hospital charges.

We designed a study to utilize the resources of our hospital information system to assess the attributable effects of ADEs on hospital length of stay and cost of hospitalization. This approach emphasized the difference between study patients and their matched control patients rather than overall differences between patients with and without ADEs. In addition, we used nursing acuity data to help adjust severity of illness within DRG groups and actual hospital costs were used instead of estimated costs.

This study found that while the average length of stay for patients with ADEs was 8.19 days compared to 4.36 days for matched control patients, the attributable difference due to the ADEs was 1.94 days. Similar methods found that patients with ADEs had an average cost of hospitalization of $10,584 compared to $5,350 for those without and the attributable difference due to ADEs was $1,939. This indicates that the 569 ADEs at our hospital during 1992 resulted in an additional 1,104 extra patient days at a cost of $1,103,291.

INTRODUCTION

Hospitalization can lead to a number of adverse events including adverse drug events, hospital-acquired infections, pulmonary embolism, falls from bed, and fatal reactions to general anesthesia. The Harvard Medical Practice Study found that patients often experienced serious long term effects from the adverse events [1]. However, this study did not attempt to determine the attributable effects of the adverse events during hospitalization.

Adverse drug events (ADEs) were the most common adverse events identified by the Harvard Medical Practice Study and other studies have estimated that as high as 10 to 20 percent of hospitalized patients may experience some type of adverse drug event [2-6]. Moderate and severe ADEs require additional treatment, hence, they contribute to the cost of hospitalization and estimates indicate that they prolong the length of stay. However, most studies to determine the cost and length of stay due to ADEs have only compared the costs and length of stays between patients with and without ADEs. In addition, most studies have not been able to link clinical information with actual cost data and have had to estimate the cost of ADEs based on hospital charges. Moreover, matched population studies that stratify patients by severity of illness and control for other adverse events have not been used to assess hospital costs and length of stay. Thus, an unknown portion of the difference in reported hospital costs and length of stay between patients with ADEs and those without was due to differences in underlying disease and other adverse advents.

Some studies have shown that nursing acuity can predict hospital length of stay as well as resource utilization [7-9]. Nursing acuity represents a measure of the nursing resources necessary to care for each patient and attempts to estimate the amount of nursing time required for each patient. Nursing acuity was initially developed to improve the management of nursing resources by calculating staffing needs and measuring productivity. Currently nursing acuity is widely used by most hospitals in the United States and a variety of automated commercial systems are available.

The purpose of this paper is to take advantage of the information provided by our hospital information system to assess the attributable effects of ADEs due to drugs administered in the hospital on hospital length of stay and

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the cost of hospitalization.

METHODS

Background

The computerized medical record on the HELP (Health Evaluation through Logical Processing) System at LDS Hospital is an ideal resource to develop methods for outcomes research. LDS Hospital is a 520-bed teaching hospital affiliated with the University of Utah School of Medicine in Salt Lake City, Utah [10]. Computer programs have been developed on the HELP System to identify ADEs [11,12]. These programs allow for voluntary reporting of ADEs by physicians, nurses, or pharmacists. In addition, logic was created within the knowledge base to automatically detect potential ADEs based on various patient signals. Each month records for patients experiencing ADEs are downloaded into database files on personal computers in the Department of Clinical Epidemiology.

The HELP System also has been used to record nursing acuity information for all inpatients since 1985 [13]. The patient acuity scores (in minutes) were calculated for each nursing shift and stored on the HELP System. The acuity system on the HELP System was developed to calculate patient acuity based on actual nursing resource use. The acuity scores are calculated based on the nurses responses to several standard questions about the care of the patient. The questions are based on objective measures of patient care for which a predetermined amount of time has been assigned. Recently, we have combined the nursing acuity data with patients' computerized medical records on the HELP System's long term archive [14]. For this study we used nursing acuity as a method to help control for severity of illness within DRGs groups.

Charge codes for patient information that impact the cost of hospitalization are automatically added to a transaction file when the information is stored in the patient's computer-based medical record on the HELP System. Each day the patient charge codes in the transaction file are sent to the hospital's financial system. The standard cost manager on the financial system provides an accurate method to determine the cost of hospitalization. It also allows for the identification of fixed/variable, direct/indirect, and marginal costs.

The HELP System at LDS Hospital has been used to identify and verify hospital-acquired infections since 1984 [15]. The criteria for hospital-acquired infections are standardized and based on the SENIC and CDC guidelines [16]. The computer algorithms are automatically activated when key information such as microbiology results are reported. Computer surveillance was found to identify more hospital-acquired infections than traditional methods and has replaced manual surveillance at LDS Hospital. Data on verified hospital-acquired infections are routinely transferred to a microcomputer to facilitate outbreak investigation and the generation of reports of infection rates.

Analysis

The data in the ADE database files for the period January 1, 1990 through July, 1992 were transferred to an Oracle database server on the LDS Hospital local area network (Figure 1). Records for patients who were hospitalized during the same time period and who had any type of hospital-acquired infection also were transferred to a file on the Oracle database server. The records of patients with hospital-acquired infections was used to identify patients with ADEs who also had hospital-acquired infections. To avoid confounding of the effect of ADEs by patients with more than one ADE or hospital-acquired infections, patients with more than one ADE and/or hospital-acquired infections were dropped from further analysis. The average nursing acuity score per shift was calculated and stored for each of the remaining study patients.

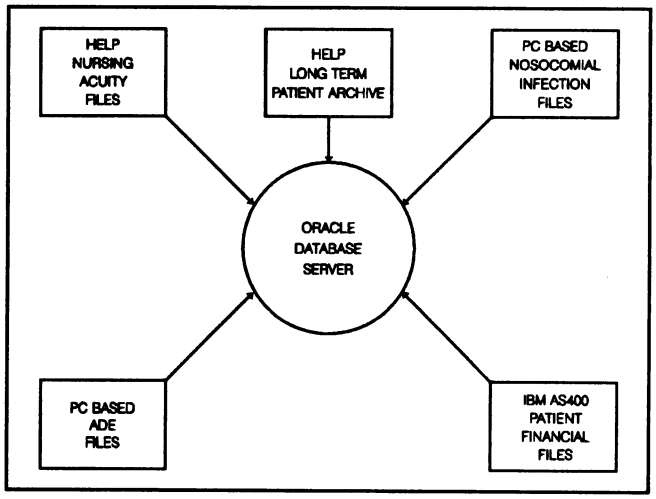

Figure 1. Description of different patient information used from the HELP System to assess the effects of adverse drug events.

A frequency distribution was created from the mean nursing acuity scores of all patients admitted to LDS Hospital during 1992. Based on this distribution we decided to use methods similar to those used by commercial severity programs and categorized nursing acuity scores into four different groups [17-19]. Since most severity programs assign 10% of patients to the most severe group, we assigned the upper 10% of nursing acuity scores to the most severe group and then divided the remaining scores into three equal ranges (group 1 = 0-150 minutes/shift, group 2 = 151-250 minutes/shift, group 3 = 251-400 minutes/shift, and group 4 = >400

minutes/shift). Once the different ranges were determined, the remaining study patients were then assigned to an acuity group based on their average nursing acuity score.

For each study patient, control patients were matched based on sex, age (+/- 10 years), exact DRG, same nursing acuity group and same year of hospitalization. The control patients were drawn from the long term patient archive from the same period January 1, 1990 through July, 1992. The control patients were sequentially selected one at a time from the archive and stored in the database. Potential control patients were not selected if they had an ADE or any type of hospital-acquired infection. Each study patient was matched to as many control patients as possible. Thus, some study patients were matched to three control patients while others were matched to as many as 20 control patients. However, each control patient was matched to only one study patient.

Because the same patient visit number is used on the HELP System and the financial system, the hospital cost data for each study and control patient was easily determined and stored in the database. A text file containing the patient visit numbers of all study and matched control patients was transferred to the IBM AS/400 financial system and used to extract the total cost of hospitalization for each patient. The text file was uploaded on the IBM AS/400 system and the IBM product "Query" was used to link the total hospital cost for each patient.

The mean length of stay and cost of hospitalization was calculated for the overall groups of study and matched control patients (Figure 2). However, a different approach was used to determine the attributable length of stay and the attributable cost of hospitalization due to ADEs. Attributable length of stay is defined as that portion of the patient's total hospital stay that can be attributed or linked to the adverse drug event. Attributable differences cannot be calculated from simple differences in group mean values [20]. To determine the true attributable difference, each study patient should be compared to its specific matched control patients. For example, the length of stay for each study patient was compared to the mean length of stay for each of the control patients matched to that specific study patient (Figure 2). Thus, if the specific study patient had been matched to 5 control patients, the length of stay of the study patient was compared to the mean length of stay for the 5 matched control patients. This procedure was repeated for each study patient and its specific matched control patients. The sum of all the differences between study patients and their matched control patients divided by the number of study patients was used as the attributable length of stay for ADEs. The same procedure was used to calculate attributable differences in total hospital cost.

A 2-sample t-test was used to detect statistically significant differences between the overall groups of study and matched control patients for hospital length of stay and cost of hospitalization. A paired t-test was used to look for statistically significant differences in attributable length of stay and cost of hospitalization. A normality test showed the data to be normally distributed.

Calculation of Length of Stay (LOS)

Study Patients	Matched Controls
A	A1, A2, A3,
B	B1, B2, B3
C	C1, C2, C3, C4,

((A+B+C)/3) -
((A1+A2+A3+B1+B2+B3+C1+C2+C3+C4)/10)
= Group Difference in LOS

(A-(A1+A2+A3)/3) + (B-(B1+B2+B3)/3) +
(C-(C1+C2+C3+C4)/4) / 3 = Attributable LOS

Figure 2. Example of method used to calculate the attributable outcomes due to adverse drug events.

RESULTS

During the 31 month period January 1, 1990 through July, 1992, a total of 60,836 inpatients were admitted to LDS Hospital. During that same time period, the HELP System was used to identify 1,348 ADEs due to drugs administered in the hospital in 1,209 different patients. Of those patients there were 982 patients who developed only one hospital acquired ADE and did not develop any type of hospital-acquired infection.

Of the 982 patients, 786 (80%) were matched to a total of 10,542 control patients. The patients were well matched for age, sex, mean acuity and DRGs (Table 1). The matched control patients had an overall mean length of stay of 4.36 days versus 8.19 days ($p < 0.05$) for patients with ADEs (Table 2). The mean overall cost of hospitalization for matched control patients was $5,350 compared to $10,584 ($p < 0.05$) for patients with ADEs. The attributable difference in length of stay between the study and control patients was found to be 1.94 days and the mean attributable difference in hospital costs was $1,939. The paired t-test was not significant for the attributable difference for length of stay ($p = 0.062$) or hospital cost ($p = 0.15$). This study shows that there is a sizable variation between using the overall difference between patient groups and the attributable difference. Thus,

overall differences can not be used to represent attributed differences even when matched control patients are used.

Because mortality is a binary variable (yes/no), we found that the approach used in this study using the paired t-test could not be used to determine the attributable difference in mortality. Moreover, attributing the death of a patient to an ADE would have to be determined by individual case review.

TABLE 1
COMPARISON BETWEEN STUDY AND CONTROL PATIENTS

	Study	Control
Mean Age	55	51
Sex (% female)	60	68
Mean Acuity	180	168
Frequent DRGs	371 359 209 106 89	371 359 209 112 106

TABLE 2
COMPARISON OF OUTCOME MEASURES BETWEEN STUDY AND CONTROL PATIENTS

	Study Patients	Control Patients	Attributable Difference
LOS (days)	8.19	4.36*	1.94
Hospital Cost	$10,584	$5,350*	$1,939

* $P < 0.05$, t Test

In this study we were unable to match 20% of our study patients. Analysis of the unmatched study patients revealed that the most common reason for lack of a match was the requirement for exact matching on discharge DRG.

DISCUSSION

The purpose of this study was to assess the effects of ADEs on hospitalized patients. Most studies of adverse events in hospital patients merely compared the differences in patients who developed adverse events with those who did not. Thus, the differences in length of stay and costs of hospitalization due to adverse events were based on the overall differences between study and control patients. However, our experience is similar to others who point out that patients who develop adverse drug events are more likely to have severe underlying diseases and some of the differences in outcome should be accounted for by the differences in the underlying diseases [21,22].

This problem prompted us to try and determine the actual attributable effects of ADEs. Thus, we decided to use a more sophisticated approach to determine the effects of ADEs. The methodology used for this study to determine attributable length of stay and cost of hospitalization emphasized the importance of difference between study patients and their specific matched controls rather than overall differences between study and control patients.

Some studies have determined the effect of hospital-acquired infections through concurrent physician review of all patients with hospital-acquired infections and determined the aspects of medical care that were directly caused by the infection [23]. This method is believed to be more accurate and results in a much smaller attributable length of stay and cost of hospital-acquired infections than studies based on differences of overall means. However, this approach is very time consuming and is subject to individual reviewer judgement.

The most common method used to control for the confounding affect of severity is to match the study patients with control patients on multiple patient characteristics. However, few studies have matched patients by a stable method to calculate severity of illness. Most studies have relied on matching numerous characteristics in a effort to compare similar patients. However, this approach usually reduces the number of study patients that can be matched. This results in many study patients being dropped from the study, often 50%, and clearly results in selection bias [20].

For this study we tried to control for severity of illness while at the same time reduce the number of matching characteristics and thus increase the number of matched patients. Therefore, we decided to match patients only by age, sex, DRG, and a severity of illness proxy, nursing acuity. This resulted in 80% of the study patients being matched to a large number of control patients. Since 15% of the study patients were not matched due to lack of control patients with the exact DRGs, matching on nursing acuity did not severely limit the matching process. For this study we decided it was important to include DRG because it is the most common method used to predict length of stay and cost of hospitalization. However, since studies have shown a difference in severity of illness within DRGs, [24] we used nursing acuity to adjust for variation of severity within DRGs. This approach follows the method used by Haley to determine the effect of hospital-acquired infections on the cost of hospitalization [20].

We have found that many patients with ADEs also develop hospital-acquired infections. Thus, we controlled for the effects of the hospital-acquired infections by dropping all study patients who also had any type of

hospital-acquired infection. However, we recognize that some of the attributable difference in length of stay and hospital cost determined by this study still may have been due to other adverse events that we were not able to identify.

Most hospitals in the United States estimate hospital costs as a percentage of charges. This method often calculates costs that are hard to justify and limits the comparison of actual costs from one institution to another. We were fortunate to be able to link the actual cost data from the financial system to the clinical data and not have to estimate cost. This was definitely an advantage provided by the hospital information system. While we currently have to access the cost data by transferring text files from one computer to another, an electronic interface between the two computers is planned for future development. This interface will automatically store all patients verified cost information in the long term archive of the HELP System.

In 1992 there were 569 ADEs identified at LDS Hospital, which based on this study would have added an average of 1,104 extra inpatient days at a cost of $1,103,291. During the years of traditional fee for service, the hospital would have recovered the cost associated with this extra length of stay by simply charging the patient or insurer. However, today with managed care which included 75% of the patients admitted to LDS Hospital in 1992, the hospital probably had to absorb most of this cost. This indicates that the prevention of ADEs would be a legitimate focus for cost containment efforts at most hospitals in the United States.

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