Contribution of Patient and Hospital Characteristics to Adverse Patient Incidents

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The 1974 medical malpractice "crisis" brought about extensive legislation and insurance regulation in the United States. Hospitals in many states are now required to support risk management programs that include investigation and systematic analyses of adverse patient incidents. However, no research supports the hypothesis that systematic analysis of adverse patient incidents can identify contributory factors. In this study, a simple prediction model was used to estimate relationships between adverse incidents and selected patient and environmental characteristics in a large hospital. While some of the incident-characteristic relationships were significant, none of the estimated equations yielded results that could be logically translated into policy recommendations for the hospital. These results point to the need for further research. The benefits that positive research results would have for patients, hospitals, and the bill-paying public are obvious. Additional negative results would suggest that many legislative bodies and regulatory agencies were presumptuous in requiring hospitals to conduct analyses of incidents.

A MAJOR component of the growth of hospital costs in the last decade is the insurance that must be taken out for professional liability or hospital malpractice. Hospitals' premiums increased more than 80 percent in 1969 and 1970; thereafter, annual increases were on the order of 10 to 20 percent, until a 64 percent increase in 1976 [1]. The American Hospital Association reports that, in 1972, $200 million was spent by hospitals for liability insurance; that figure had risen to $1.2 billion in 1977. Such insurance was estimated to account for 2.5 percent or more of overall hospital costs [2]. It has been estimated that, if the present trend continues, these costs will have increased tenfold by 1989 [3]. Such cost increases illustrate the situation popularly labeled the medical malpractice "crisis." It has been increasingly argued that the best solution to this crisis is the prevention of occurrences that are not, or may not be, "consistent with the routine care" of a particular patient in a health care facility [4].

Throughout the United States, legislation has been initiated to require hospitals to implement patient incident prevention programs, including the investigation and analysis of the frequency and causes of general categories and specific types of adverse incidents [5-9]. Further, a number of national health care organizations have supported the use of analytical methods in incident prevention programs as a basis for loss prevention efforts [10-12]. However, we found no research in related literature to support the hypothesis that systematic analytical studies yield information

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about various classes of patient incidents and the factors that contribute to them.[1]

The large Florida hospital that participated in the study prefers to remain anonymous. This significantly reduced the specific data that can be included in this report of the results. Such data on location, demographics, occupancy, and case mix, for example, could provide the reader with useful insights on the research results.

Hospital Risk Management Programs

Hospital risk management, or liability control, refers to a systematic, hospital-wide program designed to reduce preventable injuries and accidents and minimize the severity of financial claims [13]. Few such programs existed before the 1974 medical malpractice crisis. As insurance companies began to withdraw from the professional liability market, hospitals throughout the country were left with the risk of financial loss arising from malpractice claims. As a result, hospital risk management programs were implemented by several concerned hospitals and medical centers. Many state legislatures, eager to remedy the crisis, required hospitals throughout their respective states to adopt similar measures [6–8].

Some state legislatures have explicitly stated that hospital risk management programs should contain certain components. For example, in 1976, Florida's legislature passed an act requiring all hospitals to implement risk management programs that include the following:

1. investigation and analysis of the frequency and causes of general categories and specific types of adverse incidents causing injury to patients;
2. development of appropriate measures to minimize the risk of injuries and adverse incidents to patients through the cooperative efforts of all personnel;
3. analysis of patient grievances that relate to patient care and the quality of medical services; and
4. development and implementation of an incident-reporting system based upon the duty of all health care providers and all agents and employees of the health care facilty to report injuries and adverse incidents to the hospital risk manager [6].

Support for these features can be found in publications of a number of national health care organizations [10–12,14].

As evidenced by the Florida legislation, there is a consensus that risk management programs should employ analytical methods to prevent patient injuries. One of the strongest endorsements of this approach appears in a recommendation made by the Secretary of Health, Education and Welfare's Commission on Medical Malpractice:

> The Commission RECOMMENDS the development of intensified medical injury prevention programs for every health care institution in the nation, such programs to be predicated on the following:
> 1. investigation and analysis of the frequency and causes of the general categories and specific types of adverse incidents causing injury to patients;
> 2. development of appropriate measures to minimize the risk of injuries and adverse incidents to patients through the cooperative efforts of all persons. [12]

The hypothesis underlying this recommendation is that quantitative, or analytic, studies of patient incidents will identify contributory factors, which, when controlled, will prevent the occurrence of adverse patient incidents.

Our research was motivated by the possibility that incidents could be related probabilistically to patient and hospital environmental characteristics as suggested by [10-12]. This possibility is consistent with a risk management concept concerning liability: Loss reduction is the reduction of hazards found in hospital situations and conditions and in patient actions and attitudes [13]. If such relationships could be established, and if incidents could be related probabilistically to patient health impairment, court cases, and settlements, then a method to systematically reduce the latter was also possible. Hence, we focused on whether incidents could be related to patient and hospital environmental characteristics. If, say, staffing was related to incidents, the hospital could change staff. Similarly, if patients with a given personal characteristic were associated with more frequent adverse incidents, the hospital might be able to adjust resources or resource allocations accordingly. If incidents increased when there was a full moon because bright nights kept patients awake and walking in rooms and corridors, different window shades might lower the number of incidents by allowing patients to sleep. No literature was found to support or help direct the study of these kinds of questions.

The quantitative research we found in the literature was limited to listings and sorts by various characteristics included in actual incident reports [14-16]. Such data indicate what characteristics existed in settings in which adverse incidents occurred—they do not indicate whether the same characteristics existed in settings in which there were no incidents. Therefore, they do not indicate whether given characteristics are probabilistically related to incidents.

Research Hypothesis, Study Variables, and Sources of Data

The lack of systematic research on the relationship between incidents and various patient hospital environmental characteristics led us to develop a simple prediction model. The number of types of incidents per day on a nursing service was estimated, given patient characteristics, hospital environment characteristics, and their interactions on that service that day. Three types of incidents were estimated: falls, medication errors, and others. The null hypothesis is that the types of patient incidents are not a function of patient characteristics, hospital environment characteristics, or their interactions.

In testing the hypothesis, we assumed that ten nursing service units were appropriate observation units (see Table 1). For example, the importance of various numbers of a set of factors influencing incidents in a psychiatric unit was considered to be different in a surgical unit. In addition, the choice of nursing service provided a weak measure of case mix. Incidents occurring in other services such as the emergency room, clinics, and surgical suites, are not included. A linear relationship was estimated for each of the three types of incidents for each of the ten nursing service units using ordinary least squares.

Appendix A discusses the considerations and limitations that led to the simple predictive model, the observation basis, and the use of ordinary least squares for estimation. The dependent variable is the number of patients that

Table 1: Nursing Units*

Nursing Unit	Percentage of All Beds
Psychiatric	7
Pediatric	10
General Surgery	9
Surgical Specialties	13
Medical	12
Obstetrics and Gynecology	9
Ambulant	5
Adolescent	7
Surgical-Two	5
Medical-Two	3
Total	80

*The hospital had over ten thousand emergency room visits and over fifty thousand other outpatient visits during the study period, but incidents occurring in these areas are not included.

had an adverse incident during a given day in a given setting. We used frequency of incidents rather than actual claims because claims grow out of incidents and amount to less than one percent of reported incidents in the hospital. The independent variables include patient characteristics, hospital environment factors, and interactions in the settings. Patient days, a weighted census discussed below, and other factors are included in the hospital environment variable set to reflect the total care setting. This eliminated the major shortcoming of earlier studies, which consider various incidents and sets of characteristics without considering the same sets of characteristics when no incidents occurred [14-16].

Classes of the dependent variable were established by dividing the hospital's incidents into the principal injury categories used by the National Association of Insurance Commissioners (NAIC) [17]. The three most common were accidental falls, adverse effects of drugs (medication errors), and miscellaneous (other). This distribution is consistent with the distribution of claims reported to the NAIC. Appendix B contains definitions of the three incident classes.

The system used by the hospital for reporting incidents had been in existence for three years. Incidents are reported by physicians, nurses, ancillary professionals, or other hospital personnel who witness injuries or errors. The type, location, date, and other features of the incident are recorded on either an "incident report" or a "medication variance report" form. The forms are forwarded to the hospital's risk manager, who reviews them and oversees any related investigations. The reports are sorted into one of the three incident categories described above and are filed in chronological order. Incidents suggesting hospital liability have a supplementary claim file set up to facilitate additional investigation and monitoring. Effort is underway to automate the filing system to enhance loss prevention efforts.

Our study used 432 reported incidents (see Table 2). Data were collected for each day in January, March, May, July, September, and November 1977. We selected alternate months to control for possible seasonal effects. Each day in each recorded month was treated as an observation unit, yielding a total of 184. The patient factors included physical, medical, financial, religious, and attitude characteristics of patients in locations where incidents were reported. Similarly, hospital factors included physical, work load, staffing, education, and environmental characteristics of locations where patients received routine daily care.

We developed specific factors on the basis of a review of related literature [18,19] and interviews with key hospital personnel. The limited availability of daily measures for each of the ten nursing units restricted the investigation to an analysis of 23 patient-characteristic and hospital-environment variables. Since the study was exploratory, we added several environment factors that were available from hospital records but that were not found in related literature or suggested by hospital variables. This gave us 36 interaction variables, bringing the total number of explanatory variables studied to 59. Table 3 contains definitions of the dependent and independent variables used in the study.[2]

Results

None of the 30 estimated equations gave results from which logical policy recommendations could be made. The highest R^2, 0.489, was for medication errors on the surgical-two unit (Table 4). Although significant at conventional levels, the findings did little to explain why incidents occurred. More important, the significant beta coefficients in the estimate did not allow us to develop recommendations that might help the hospital reduce incidents. Table 5 shows the beta coefficients significant at the 0.01 level from all 30 estimated equations. Others tests indicated that multicollinearity among patient and environment variables was not a problem.

The estimate for MEDERROR surgical-two unit did not include any hospital environment factor significant at the 0.01 level. Two patient characteristics, CHRISTIN and OTHERELIG, were significant at 0.01. Significant (0.01) interaction variables gave contradictory results. Medication errors on the unit were negatively related to greater numbers of patients and greater numbers of indigent patients (INDI*PATDAY). Conversely, medication errors on the unit were positively related to more nursing staff on duty and to greater numbers of self-paying patients (SELF*NURS) but negatively related to more indigent patients and more

Table 2:
Distribution of Incidents by Type*

Incident	Number	Percent
Accidental Falls	166	38
Medication Errors	137	32
Other Incidents	129	30
Total	432	100

*In the aggregate, there was a 0.0081 chance of a patient experiencing an incident on any given day of the study (incidents per patient day = 0.0081).

Table 3: Definition of Variables

Variable	Definition
	Dependent Variables
FALLS	Unintentional falls by patients
MEDERROR	Erroneous administration of drugs and intravenous solutions
OTHERROR	Other adverse incidents
	Independent Patient Variables
LESSCARE	Needing less than routine care
INTCAREPT	Needing above average or intensive care
LONGSTAYPT	On a nursing unit 12 days or longer
PEDPT	Age 15 and under
ELDER	Age 60 and over
MALE	Men
MARRIED	Married
JEWISH	Jewish
CHRISTN	Protestant or Roman Catholic
OTHERELIG	Other religious denominations
SELFPAY	Full and personal responsibility for hospital charges
INSURPT	Some form of third party coverage for hospital charges
INDIGENT	Unable to pay hospital charges
COMPLNT	Written or verbal complaints filed with the patient relations department about nursing care, housekeeping, or other patient services
	Independent Hospital Variables
WORKLOAD	Number of patients processed for discharge or transfer out of the nursing unit
PATDAY	Number of patients on the unit at the census-taking hour, weighted by three nursing care factors
NURSTAFF	Full-time nursing staff on duty, including RNs, LPNs, and NAs
RNSTAFF	Ratio of RNs to total nursing staff
MNTVISIT	Equipment repairs, preventive maintenance checks, and emergency repairs or replacements on the unit
EXHOKEEP	Housekeeping staff is twice the average number
INSERVED	In-service education program on the unit
RNLESSEX	RNs with less than one month's working experience in the hospital
FULLMOON	Occurrence of a full moon
	Interaction Variables
INT*WORK	INTCAREPT with WORKLOAD
INT*PATDAY	INTCAREPT with PATDAY

Table 3: *continued*

Variable	Definition
INT*NURS	INTCAREPT with NURSTAFF
INT*RN	INTCAREPT with RNSTAFF
INT*RNLESSEX	INTCAREPT with RNLESSEX
INT*FULL	INTCAREPT with FULLMOON
LONG*WORK	LONGSTAYPT with WORKLOAD
LONG*PATDAY	LONGSTAYPT with PATDAY
LONG*NURS	LONGSTAYPT with NURSTAFF
LONG*RN	LONGSTAYPT with RNSTAFF
LONG*RNLESSEX	LONGSTAYPT with RNLESSEX
LONG*FULL	LONGSTAYPT with FULLMOON
JEW*WORK	JEWISH with WORKLOAD
JEW*PATDAY	JEWISH with PATDAY
JEW*NURS	JEWISH with NURSTAFF
JEW*RN	JEWISH with RNSTAFF
JEW*RNLESSEX	JEWISH with RNLESSEX
JEW*FULL	JEWISH with FULLMOON
SELF*WORK	SELFPAY with WORKLOAD
SELF*PATDAY	SELFPAY with PATDAY
WORK*NURS	SELFPAY with NURSTAFF
WORK*RN	SELFPAY with RNSTAFF
SELF*RNLESSEX	SELFPAY with RNLESSEX
SELF*FULL	SELFPAY with FULLMOON
INDI*WORK	INDIGENT with WORKLOAD
INDI*PATDAY	INDIGENT with PATDAY
INDI*NURS	INDIGENT with NURSTAFF
INDI*RN	INDIGENT with RNSTAFF
INDI*RNLESSEX	INDIGENT with RNLESSEX
INDI*FULL	INDIGENT with FULLMOON
COMP*WORK	COMPLNT with WORKLOAD
COMP*PATDAY	COMPLNT with PATDAY
COMP*NURS	COMPLNT with NURSTAFF
COMP*RN	COMPLNT with RNSTAFF
COMP*RNLESSEX	COMPLNT with RNLESSEX
COMP*FULL	COMPLNT with FULLMOON

nursing staff on duty (INDI*NURS). A more general interaction variable for nursing staff and patient day, which was included in preliminary estimates, was not found to be significant in any equation.

Overall, there was no consistent pattern of significant variables across nursing units at the 0.01 level (or at the 0.05 level). Of the 30 estimates, 17 did not include any significant beta coefficients at the 0.01 level (Table 6). Six of the estimates did not include significant coefficients at the 0.05 level. Only 28 (1.6 percent) of the 1,770 estimated beta coefficients were significant at the 0.05 level. Using a simple difference between proportions test (assum-

Table 4:
MEDERROR Regression Data for the Surgical-Two Unit

Variable†	Coefficient	Standard Error	F Value
Patient			
LESSCARE	-0.000	0.008	0.00
INTCAREPT	-0.012	0.009	1.81
LONGSTAYPT	0.080	0.075	1.13
PEDPT	0.000	0.007	0.00
ELDER	0.005	0.003	2.57
MALE	0.006	0.003	3.09
MARRIED	0.003	0.005	0.53
JEWISH	0.073	0.075	0.93
CHRISTN	-0.015	0.005	10.74§
OTHERELIG	-0.021	0.007	9.61§
SELFPAY	0.022	0.057	0.15
INSURPT	0.010	0.004	6.62‖
INDIGENT	-0.002	0.038	0.00
COMPLNT	0.000	0.000	0.00
Hospital			
WORKLOAD	-0.006	0.008	0.53
PATDAY	0.006	0.004	3.28
NURSTAFF	0.006	0.008	0.37
RNSTAFF	0.134	0.220	0.37
MNTVISIT	0.001	0.010	0.01
EXHOKEEP	0.011	0.017	0.37
INSERVED	0.005	0.034	0.02
RNLESSEX	-0.057	0.095	0.36
FULLMOON	0.141	0.261	0.29
Interaction			
INT*WORK	0.001	0.001	0.85
INT*PATDAY	0.000	0.000	1.81
INT*NURS	0.000	0.000	0.09
INT*RN	-0.018	0.014	1.57
INT*RNLESSEX	0.001	0.006	0.02
INT*FULL	-0.021	0.038	0.29
LONG*WORK	-0.000	0.003	0.00
LONG*PATDAY	-0.000	0.001	0.10
LONG*NURS	-0.003	0.004	0.63
LONG*RN	-0.090	0.105	0.74
LONG*RNLESSEX	0.040	0.066	0.37
LONG*FULL	0.016	0.054	0.09
JEW*WORK	-0.007	0.005	1.92
JEW*PATDAY	0.001	0.002	0.15
JEW*NURS	-0.002	0.004	0.31
JEW*RN	-0.089	0.149	0.36

Table 4: *continued*

Variable†	Coefficient	Standard Error	F Value
JEW*RNLESSEX	-0.089	0.098	0.84
JEW*FULL	0.025	0.120	0.04
SELF*WORK	-0.002	0.003	0.45
SELF*PATDAY	-0.004	0.000	24.63§
SELF*NURS	0.010	0.003	9.16§
SELF*RN	0.015	0.081	0.03
SELF*RNLESSEX	0.054	0.064	0.70
SELF*FULL	0.113	0.203	0.31
INDI*WORK	0.004	0.002	5.34‖
INDI*PATDAY	0.002	0.001	12.08§
INDI*NURS	-0.007	0.002	10.60§
INDI*RN	0.021	0.056	0.14
INDI*RNLESSEX	0.009	0.015	0.33
INDI*FULL	-0.006	0.028	0.05
COMP*WORK	0.000	0.000	0.00
COMP*PATDAY	0.000	0.000	0.00
COMP*NURS	0.000	0.000	0.00
COMP*RN	0.000	0.000	0.00
COMP*RNLESSEX	0.000	0.000	0.00
COMP*FULL	0.000	0.000	0.00

†Variable definitions are given in Table 3.
‡F (52,113) = 2.08. Theoretical F (60,120) = 1.47 @ .01; 1.32 @ 0.05. R^2 = 0.489.
§Significant at the 0.01 level.
‖Significant at the 0.05 level.

Table 5:
Variables from 30 Estimates
(Significant at 0.01 Level)

Dependent Variable	Nursing Unit	Independent Variable	Level of Significance	
Accidental	Psychiatric	INTCAREPT	0.003	+
Falls	Pediatric	FULLMOON	0.001	+
		INDI*FULL	0.001	-
		JEW*FULL	0.004	-
	Obstetrics and	RNLESSEX	0.001	+
	Gynecology	INT*RNLESSEX	0.001	-
	Adolescent	CHRISTN	0.004	+
Medication	Pediatric	SELF*NURS	0.003	-
Errors	General Surgery	JEW*WORK	0.010	+
	Medical	EXHOKEEP	0.001	+

Table 5: *continued*

Dependent Variable	Nursing Unit	Independent Variable	Level of Significance	
		LONG*WORK	0.006	+
	Ambulant	INT*RNLESSEX	0.001	+
		INT*FULL	0.004	-
		INDI*RNLESSEX	0.007	-
	Adolescent	INDI*WORK	0.003	-
	Surgical-Two	CHRISTN	0.001	-
		OTHRELIG	0.002	-
		SELF*PATDAY	0.001	-
		INDI*PATDAY	0.001	+
		INDI*NURS	0.001	-
		SELF*NURS	0.003	+
Other Incidents	Pediatric	JEW*RNLESSEX	0.003	+
		INDI*RNLESSEX	0.007	+
		JEW*FULL	0.010	-
		INDI*FULL	0.010	-
	Surgical-Two	LONG*RNLESSEX	0.003	-
	Medical-Two	MALE	0.001	+
		INDI*FULL	0.001	-

ing the 0.05 is not too close to 0), it follows that these aggregate results could easily have been found by drawing sample data from random numbers ($t = -0.055$).

At the 0.01 level, only 2 hospital environment factors were significant: RNLESSES for FALLS in the obstetrics and gynecology unit and EXHOKEEP for MEDERROR in the medical unit. Variables for the interaction of hospital environment and patient characteristics entered estimates only 13 times, while FULLMOON entered estimates independently or through interaction with other variables 7 times at the 0.01 level. There was no difference in the occurrence of significant variables by type at the 0.05 level and higher. Using 30 equations, we estimated 1,080 beta coefficients for interaction variables, one fewer than the 55 that were significant at the 0.05 level or higher. Similarly, 5 percent of the variable beta coefficients estimated is 34—33 were significant at the 5 percent level or higher. Hence, the results do not suggest what types of variables should be used in future reearch.

Estimates were also made without using nursing unit partitions, thus expanding the replication of cases. Linear and log-linear estimates were made by pooling the dependent and independent variables. The results are shown in Table 7. While all the estimates were significant at the 0.01 level (because of the size of n), they explain little; multicollinearity among patient and environment variables was a problem. Further, the R^2 values

Table 6:
Summary Measures of Equation 7

Type of Incident*	Nursing Unit	R^2	F(52,113)†	Significant Variables‡ (at 0.05)	Significant Variables‡ (at 0.01)
Accidental Falls	Psychiatric	0.243	0.70	2	1
	Pediatric	0.352	1.18	1	3
	General Surgery	0.190	0.48	0	0
	Surgical Specialties	0.249	0.72	0	0
	Medical	0.267	0.77	1	0
	Obstetrics and Gynecology	0.394	1.39	1	2
	Ambulant	0.230	0.62	0	0
	Adolescent	0.331	1.16	4	1
	Surgical-Two	0.272	0.81	0	0
	Medical-Two	0.323	0.17	5	0
Medication Errors	Psychiatric	0.138	0.35	0	0
	Pediatric	0.370	1.28	5	1
	General Surgery	0.348	1.09	1	1
	Surgical Specialties	0.303	0.94	1	0
	Medical	0.391	1.36	3	2
	Obstetrics and Gynecology	0.274	0.80	3	0
	Ambulant	0.408	1.44	1	3
	Adolescent	0.372	1.38	4	1
	Surgical-Two	0.489	2.08	2	6
	Medical-Two	0.317	1.04	3	0
Other Incidents	Psychiatric	0.357	1.21	2	0
	Pediatric	0.329	1.06	5	4
	General Surgery	0.257	0.70	2	0
	Surgical Specialties	0.331	1.07	2	0
	Medical	0.251	0.71	2	0
	Obstetrics and Gynecology	0.222	0.61	2	0
	Ambulant	0.199	0.52	1	0
	Adolescent	0.172	0.49	0	0
	Surgical-Two	0.278	0.84	4	1
	Medical-Two	0.457	1.88	3	2

*The types of incidents are defined in Appendix B.
†Theoretical $F(60,120)$ = 1.47 @ 0.01; 1.32 @ 0.05.
‡Total variables significant at the 0.05 level or better, 88; at the 0.01 level or better, 28.

were all substantially lower than those found when nursing units were divided into categories (see Table 6). This finding tentatively suggests that nursing units may be of value as design partitions in future studies.

Conclusions and Implications

The results clearly imply that adverse patient incidents cannot be predicted by observing the patient characteristic and hospital environment

Table 7: Estimates of Incidents Pooled over Nursing Stations

Dependent Variable	Estimation Form	R^2	F(57,1615)*
Accidental Falls	Linear	0.056	1.67
	Log-Linear	0.054	1.63
Medication Errors	Linear	0.079	2.43
	Log-Linear	0.065	1.99
Other Incidents	Linear	0.054	1.62
	Log-Linear	0.068	2.09

*Theoretical $F(60, \infty) = 1.47$ at 0.01.

factors used in this study. In no case did the results suggest policies or practices that hospital management might find useful in reducing the number of incidents. However, the results do suggest that the authors of related literature and legislation may have been presumptuous in assuming that patient injuries could be prevented by requiring hospitals to study the frequency and characteristics of incidents. Our study only maintained the null hypothesis for one hospital's experience, and we were constrained in our use of data. No research has demonstrated that the costly studies required of hospitals are effective.

One implication of the study's statistical results is that each incident may have a unique set of contributing factors, which would preclude the use of factor effects in making reliable predictions of similar incidents. This is not to say that incident, patient, and hospital environment data should not be recorded and stored for analysis: A major limitation of this and other related research has been the unavailability of such data [16,20-22]. Rather, injury prevention programs should focus on the details of each incident as it occurs. Investigative findings may lead to specific corrective action.

As more complete data on patient injuries become available, hospitals may be able to develop prevention policies using empirical studies [23]. However, legislators and national health care spokesmen must recognize that it is erroneous to assume that health care organizations that are not recording sufficient data can conduct more meaningful analytic studies. Moreover, governmental bodies should support research efforts, which could lead to greater cost-effectiveness in hospitals. They should not aggravate an already critical situation by imposing costly requirements that have no basis in theory or practice.

The results also suggest some directions for future research. Categorizing patients by the type of nursing care they require, for example, appears preferable to the pooling of all patients. Our design, which encompassed daily observations of incidents, patient characteristics, and hospital environment factors for a single hospital, was not useful. A nursing shift as an observation unit was considered early in this research, but limitations on our data precluded its use. Perhaps a design that includes data collection over a planned period would eliminate many of the limitations imposed on this study by available data.

In this study, patients' incident and related data for each day at a nursing station were aggregated for observations. A logical alternative would be to measure incident and related data for each patient day at a nursing station or for each patient at each shift at a nursing station [per Equation (2) in Appendix B]. The incident measure would be 1 for an incident and 0 for no incident. The relationship between the (0,1) dependent variables and independent variables could be estimated with a logit procedure. The resulting beta weights would give incident probabilities related to the explanatory variables.

It should be noted that this study was a first step in the systematic analysis of patient incidents. The results are not sufficient to conclude whether or not such studies can provide an empirical basis for reducing adverse patient incidents in hospitals. This attempt to formally incorporate hospital practices, professional opinions, and legislative requirements in a simple predictive model for one hospital proved unsuccessful. Similar results could be found by sampling from random numbers. However, this initial research effort prompts a number of questions: Is the model erroneously specified? Are preventive ideas in the literature and legislation wrong? Are incidents in hospitals correctly described as a random process? Researched answers to these questions could help formulate reasoned public policy for countering the nation's malpractice crisis.

APPENDIX A: MODEL DEVELOPMENT AND ESTIMATION METHODOLOGY

We attempt to answer a question about risk management that has apparently been assumed as validated by various legislative bodies throughout the country: Can incidents be predicted for given patient (P) and hospital environment (E) characteristics? The development of the predictive model used in this study to address the question included the following considerations. The literature suggests that incidents (Y) are a function of P, E, and/or their interaction (PE):

$$Y = f(P, E, PE). \tag{1}$$

For example, an alert ambulatory patient could fall while walking in an area with no hazards, $Y = f(P)$. An alert patient could fall after being given the wrong medication, $Y = f(E)$. A sedated patient, otherwise alert, could fall from a bed because the attendant moving him slipped on a wet floor, $Y = f(PE)$. We record the actual incident experienced by the patient and place it in one of three categories: accidental falls, medication errors, and other incidents.

In a given time frame, a patient with a set of measurable characteristics in a hospital location with a set of measurable characteristics either does or does not experience an incident. If no incident occurs, Y is zero for that patient. If an incident does take place, the question arises, How should Y be measured? Marginal impairment of patient health and marginal cost to the hospital were ruled out as possibilities because of quantification problems in making direct estimates for all patients experiencing incidents. If only patients who experienced incidents requiring negotiated or court settlements were considered, the number of nonzero dependent variables would be too small for any significant statistical results. Hence, the available information on a patient's incident was used, the condition 1 indicating that an incident took place. This is a gross measure, one dictated by the realities of measurement limitations.

Thus the basic model construct was established. In a given time frame for n patients with a set P and a set E, there exists a matrix:

Patient	Y	P	E	
1	0	$p_{1,1}, p_{1,2}, \ldots, p_{1,m}$	$e_{1,1}, e_{1,2}, \ldots, e_{1,k}$	
2	0	$p_{2,1}, p_{2,2}, \ldots, p_{2,m}$	$e_{2,1}, e_{2,2}, \ldots, e_{2,k}$	
3	1	$p_{3,1}, p_{3,2}, \ldots, p_{3,m}$	$e_{3,1}, e_{3,2}, \ldots, e_{3,k}$	(2)
	. . .			
n	0	$p_{n,1}, p_{n,2}, \ldots, p_{n,m}$	$e_{n,1}, e_{n,2}, \ldots, e_{n,k}$	

One objective of the research was to determine whether any systematic relationships could be found. Such relationships suggest that the hospital management either modify controllable E characteristics or plan procedures that anticipate given E and P characteristics, when possible, so the number of incidents could be reduced. The data construct in Equation (2) could be analyzed using logit procedures, but practical realities constrained the research. Data did not exist to build the construct in Equation (2). Enough hospital reports did exist to build the following vector for n patients in each nursing unit for each day for each type of incident:

$$\sum_n Y \quad \sum_n p_1 \quad \sum_n p_2 \quad \cdots \quad \sum_n p_m \quad \sum_n e_1 \quad \sum_n e_2 \quad \cdots \quad \sum_n e_k \,. \tag{3}$$

We initially thought the aggregations in Equation (3) could be done by nursing shift, instead of by day. However, data by shift were not available for many variables.

Equation (3), a column by column summation of Equation (2), can be restated in the form used in Equation (1), where $X = \Sigma Y$. X is the number of incidents on a nursing service for a day for each of the three types of incidents considered in the study.

$$X = f(P, E, PE). \tag{4}$$

The relationship in Equation (4) in the context of the study observation base is

$$X_t = f(p_{i,t}, e_{i,t}, pe_{i,t}), \tag{5}$$

where X_t is the number of incidents in each injury classification in the tth time period (24 hours), $e_{i,t}$ is the ith environment factor of a nursing service in the tth time period, and $p_{i,t}$ is the ith characteristic of patients in a nursing station in the tth time period; $pe_{i,t}$ are interaction terms.

A set of 23 patient and environment factors was considered, $e'_{i,t}$ and $p'_{i,t}$, as a subset of all possible factors. Hence, the excluded factors, $e''_{i,t}$ and $p''_{i,t}$, are assumed as given, with randomly distributed effects. Therefore, the relationship estimated for each nursing station and type of incident is

$$X_t = f(e'_{i,t},\ p'_{i,t},\ pe'_{i,t} \mid e''_{i,t}, p''_{i,t}). \tag{6}$$

A linear relationship was estimated for each nursing station,

$$X_t = B_o + B_i e'_{i,t} + B_j p'_{j,t} + B_k pe'_{k,t} + v_t, \tag{7}$$

using ordinary least squares, assuming the error term is normally distributed with a mean equal to 0 and a variance σt^2, ($v_t \sim N(0, \sigma t2)$). This estimation method is supported by conclusions in [10,12,24].

The estimation form was motivated by the nature of the variables available for study. Most of the included variables were continuous (cardinal) measures of patient and environment characteristics. Hence, the linear form was first used, since the variable coefficients permitted marginal measures of contributions by the various characteristics to incidents. The results of the linear analyses led to the association measures given by Spearman rank correlation coefficients; they did not differ in substance from the results reported in this article.

Other estimation forms were considered. As noted above, data limitations precluded the use of logit. Another alternative was to divide the dependent variable (the number of incidents) by patient days (midnight census), exclude patient days from the independent variables (to avoid specification errors), and use probit for the estimations. This choice was not aided by theory, and the lack of multicollinearity problems led to the presentation of ordinary least squares results.

APPENDIX B: DEFINITIONS OF INCIDENT CLASSES

Accidental Falls (FALLS). An accidental fall was defined as an unintentional fall by a patient. Falls of visitors and staff members were not used in the study. The following types of recorded falls were included in this category:

- Falls—different levels
  - From bed
    - Rails up
    - Rails down
    - Rail position not indicated
  - From chair, wheelchair, stool
  - From stretcher
  - From table
  - Not otherwise classified
- Falls—same level
  - Patient room
  - Patient bathroom
  - Corridor
  - Waiting area
  - Not otherwise classified
- Falls—transportation
- Falls—equipment malfunction.

Medication Errors (MEDERROR). A medication error was defined as an erroneous administration of both drugs and intravenous solutions. The following types of reported incidents were included in this category:

- Drug variances
  - Wrong patient
  - Wrong drug
  - Wrong dosage
  - Wrong route
  - Wrong time
  - In wrong site
  - Out-of-date drug
  - Out of date order
  - Adverse drug response
  - Medication self-administered
  - Medication not given
  - Discontinued medication given
  - Communication
  - Drugs unavailable
  - Pharmacy error
  - Drug incompatability
  - Defective equipment
  - Not otherwise classified
- Transfusion-intravenous solution
  - Wrong dosage
  - Wrong rate
  - Wrong time
  - Wrong patient
  - Infection
  - Wrong medication
  - Wrong fluid or solution
  - Equipment malfunction
  - Not otherwise classified

Other Incidents (OTHERROR). All other reported incidents were screened by the hospital's manager to determine their appropriateness for inclusion in the study. For example, the loss of a patient's article of clothing was not considered to be a patient incident, even though this type of event was reported and was on file as such. Only the following types of incidents were included in the OTHERROR category:

- Dietary
  - Wrong patient
  - Foreign matter in food or drink
  - Orally restricted patient given food or drink
  - Not otherwise classified
- Improper care or treatment
  - Wrong time
  - Wrong patient
  - Wrong body part
  - Wrong procedure

Without permit
Equipment malfunction
Not otherwise classified
Diagnostic procedures
Wrong time
Wrong patient
Wrong body part
Wrong procedure
Without permit
Incomplete permit
Equipment malfunction
Not otherwise classified
Miscellaneous
Temperature extremes
Struck by
Struck against
Caught in, on, between (pinch points)
Smoking
Intentional self-harm
Assault or battery
Animal or insect bite
Human bite
Patient behavior
Procedure variance
Equipment failure

END NOTES

[1]The literature review included the following insurance journals and trade publications from January 1975 to January 1980: *Journal of Risk and Insurance, Bests' Review, Risk Management, Insurance Law Journal, Journal of American Insurance, Rough Notes, National Underwriter, Weekly Underwriter,* and *Insurance Salesman.* It also included the following health journals: *Inquiry, Health Services Research,* and *Hospitals, Journal of the American Hospital Association.*

[2]A table containing the means and standard deviations of the variables (with 1,240 entires) is available from the authors.

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