

Adverse Patient Safety Events: Who Gets Them and How Much Does it Matter?

By Karen Mahaffey  
Advisor: Dr. Marsha Goldfarb  
August 4, 2004

## Introduction/Problem Definition

In 1997, 33.6 million people entered the hospital hoping to improve their health status. Between 44,000 and 98,000 died as a result of medical errors. (Institute of Medicine, 1999) Statistics from this Institute of Medicine report have been cited in studies for the past four years. Though the actual numbers were hard to determine then, and still are, the hard truth is that of the approximately 34 million patients admitted to the hospital each year, many will receive an unanticipated and unwelcome consequence of their hospital stay. Medical errors (adverse patient safety events) result from sources such as incorrect drug prescriptions, foreign bodies left in during a surgical procedure, or hospital acquired (nosocomial) infections.

While infection from a hospital procedure is an inherent risk in many cases, the fact remains that patients acquire infections that are not a natural consequence of the procedure but due to preventable quality of care issues. This paper looks at the randomness of infection as well as other adverse events. The question of who sustains adverse events is of importance to health services personnel to establish prevention practices. The consequence of the event is an economic question of interest.

From a moral view, medical errors cause unnecessary pain and suffering. Patients take longer to recover, are sicker, and sometimes die as a result of the adverse events, all of which affect the patient and his family. The patient's right to quality care has been violated, as has the doctor's mandate to "do no harm".

From an economic point of view, the costs of medical errors may be unacceptable. The costs involved depend on the view taken. From society's view, resources are not allocated efficiently. Medical staff, drugs, and other hospital resources are being used in the treatment of these errors instead of an alternative use. The alternative uses are not hard to imagine. About 45

million Americans are uninsured, millions more are underinsured, health care costs are on a steady incline, and nurse shortages are the norm. Resources used unnecessarily to treat the consequences of medical errors could be used to provide insurance for the uninsured, subsidize medical research, pay for preventive care services, or for provision of other public or private goods. Lost productivity is a concern on both a macro and micro level.

From the patient's point of view, there are direct costs involved, most notably to those who are uninsured or self-insured. Patients may have to pay higher out-of-pocket charges when they are billed for the additional services needed to treat the medical error. In the current economy the percentage of low wage part-time workers with few or no benefits such as sick leave has increased. When these workers can not work as a result of an adverse event, they do not get paid. The impact on these families can be enormous although these indirect costs are usually not calculated in the costs associated with medical errors.

From the hospital and doctor's view there is a loss to their reputations that impacts future business to the extent that consumer's knowledge of these errors is known. But herein lies another problem. Hospitals are not required to report cases such as hospital-acquired infections. This gives them an unfair advantage as a consequence of asymmetric information. Patients (consumers) will choose the "best" hospital and doctor based on their best knowledge, which is incomplete. If blame can be identified for the adverse event, litigation becomes another associated cost. Higher costs of malpractice insurance will result in either higher charges to the patient or will force hospitals to cut their spending on the provision of other services.

From the insurer's point of view, higher bills associated with the additional services needed to treat the medical error may not be paid. According to the CDC (2000) this means the hospital must absorb the excess charges. However, in the long-term, higher bills created by

medical errors will lead to higher reimbursements and higher premiums, imposing an opportunity cost on policy holders (private insurance) and taxpayers (public insurance).

While much of the literature related to nosocomial infections and other medical errors tries to define the extent of the problem, the primary focus has been on getting the medical community to put programs in place to prevent infections as a matter of better care. This is the ultimate goal, but decision makers often need an incentive to undertake additional and costly new programs and procedures. An economic analysis of the costs of medical errors and their distributional impacts can give just such an incentive.

### Literature Review

As mentioned earlier, the seminal publication and the one most often cited is the Institute of Medicine's (1999) publication *To Err is Human: Building a Safer Health System*. This publication stirred interest by researchers and the media, and prompted the President to create a commission on the quality of patient care.

Some studies have quantified the costs for the entire category of medical errors. Others identify specific areas of concern. A publication of the Agency for Healthcare Research and Quality (AHRQ, Migdail and Murray, 2000) summarized studies that found adverse events due to surgical procedures represented 2/3 of all adverse events and adverse drug events accounted for one out of five injuries to patients.

Studies show that other countries face the same problem to varying degrees. A recent Canadian study (Norton, 2004) estimated adverse events at 7.5% nationally, compared to 2.9% in the U.S. and 16.6 % in Australia.

Hospital level studies are those undertaken most often. Economic modeling (Roberts, Scott, et al, 2003) showed an excess \$15,275 cost to the hospital for a confirmed case of hospital

acquired infection and \$6,767 for suspected infections. They (Roberts, Scott, et al, 2003) find, as does the CDC (2000), that hospitals usually bear the cost of hospital acquired infections, not the third-party payor. An audit of studies related to the economics of nosocomial infections (Stone, Larson, Kavar, 2002) found that 48 out of 55 studies were done from the hospital perspective. They (Stone, Larson, Kavar, 2002) found marginal costs from bloodstream infections to be the highest, with a mean of \$38,703.

A recent study by Zhan and Miller (2003) sought to examine costs in terms of excess mortality, hospital length of stay (LOS), and total charges. They found that excess LOS ranges from 0 to 10.89 days depending on the adverse effect. Excess total charges ranged from \$0 to \$57,727 per affected patient and mortality was 0% to 21.92% above that of unaffected patients. This study is of particular interest as theirs was the only study using the NIS dataset and PSI software that I will use.

Limits of the studies, which I have noticed, were discussed also in the Zhan and Miller (2003) study. Definitive estimates of the incidence and impact of medical errors are extremely difficult to obtain in practice due to several obstacles. Most notable are:

- 1) Not every adverse event is proof of poor medical practice. As mentioned earlier, some degree of infection is a risk associated with hospital procedures as a normal course of the recovery process. Trying to distinguish between naturally occurring adverse effects and those occurring as a result of preventable quality of care problems is difficult.
- 2) Defining the proper risk pool has been an obstacle in the past. Rather than identifying adverse events as a consequence of any hospital stay, the event needs to be related to the risk the patient faces. For example a case of Postoperative Sepsis<sup>1</sup> would not be a risk for patients who did not have surgery. Also, for immunocompromised patients, the opportunity for infection is extremely high and their inclusion in the risk pool would unduly bias the findings.
- 3) Identifying the presence of an adverse event is another challenge. In past studies, especially those pertaining to specific hospitals, researchers performed a medical

---

<sup>1</sup> Sepsis is an illness caused by bacterial infection of the bloodstream.

chart review searching for the condition of interest. Two problems are related to this process. The depth or completeness of the records is often not enough to ascertain whether the condition existed. Moreover, the researcher may not have enough medical knowledge to adequately determine the existence of the condition based on the records.

- 4) In addition to the inadequacies of examining the records as a data source, the process of gaining access to the data is difficult.

While the limits of imperfect data collection present obstacles, the extent of the problem of adverse patient safety events necessitate that the studies go on and we must do the best we can with the data that is readily available. Fortunately a large database of hospital administrative data exists and is available to me.

### Data Description

The Healthcare Cost and Utilization Project, a component of AHRQ, makes available a database called the Nationwide Inpatient Sample (NIS). The 2001 NIS contains approximately 7.4 million inpatient discharge records from 986 hospitals in 33 states, weighted to approximate a 20% sample representing all community hospitals in the U.S. Data elements include characteristics of the patient himself, such as race, sex, age, and insurance status; descriptors of their stay in the hospital such as the primary and secondary diagnoses, procedures, charges and LOS; and basic characteristics of the hospital such as location, bed size and teaching status.

Major advantages of the NIS database are that it is national in scope, it is affordable, and it provides a significant amount of clinical and demographic detail. In addition, AHRQ created software that can be applied to the NIS database to identify twenty preventable adverse events called Patient Safety Indicators (PSIs). The software identifies only those patients with the PSI who are part of the appropriate risk pool. In other words, it selects only those records for which these patients might develop a PSI under preventable conditions.

This study will look at three PSIs. The three I have chosen are Selected Infections Due to Medical Care, Postoperative Sepsis, and Decubitus Ulcer. These adverse patient safety events are of interest for different reasons.

Selected Infections Due to Medical Care (infections primarily from IV lines and catheters) has a relatively low incidence rate but is of interest because the risk pool is so large. The risk pool for Selected Infections Due to Medical Care includes all medical and surgical discharges except those with cancer or an immunocompromised state. If nearly every inpatient is at risk, the question of who contracts the infection has wider implications.

Decubitus Ulcer, otherwise known as bedsores, has a relatively high incidence rate but has more opportunities for prevention, allowing for cost effective remedies. The risk pool for Decubitus Ulcer includes all medical and surgical patients with a LOS of over 4 days, but excludes patients with paralysis and those admitted from long-term care facilities.

Postoperative Sepsis, on the other hand, is very serious and has substantial consequences for costs and mortality.<sup>2</sup> The risk pool for Postoperative Sepsis includes surgical patients with a LOS greater than 3 days, but excludes patients with immunocompromised state or cancer.

The recent Zhan and Miller (2003) article is the first and only one, to my knowledge, to study this topic using the PSI software and the NIS database. In my study I am exploring somewhat different aspects of the patient safety issue. For example, one component of my study will not only estimate the average excess charges and length of stay associated with my three selected PSIs, but will also attempt to differentiate the costs based on patient and hospital characteristics. The Zhan and Miller (2003) article will serve as an informal validity check of

---

<sup>2</sup> Of the 18 PSIs studied, Zhan and Miller associate the highest excess LOS, charges, and mortality with Postoperative Sepsis.

my results. Another difference with the Zhan and Miller (2003) article is that I will explore which types of patients are more or less likely to suffer an adverse patient safety event.

Descriptive Statistics

The following tables present a picture of the datasets used for my project. Looking at Table 1, the difference in means of the patients without a PSI and those with a PSI gives a picture of the seriousness of the adverse event. In all cases, the presence of a PSI is associated with a larger number of diagnoses and procedures, and raises total charges and length of stay. Of course, other confounding variables are not controlled for here.

Table 1 Differences in Means by presence or absence of Patient Safety Indicator

	Postoperative Sepsis (n=46,843) Rate = 1.06%		Infection Due to Medical Care (n=289,254) Rate = 0.21%		Decubitus Ulcer (n=376,630) Rate = 2.35%	
	Without PSI N=46,348	With PSI N=495	Without PSI N=288,648	With PSI N=606	Without PSI N=367,781	With PSI N=8,849
Total Charges	\$34,667	\$123,853	\$15,007	\$89,622	\$30,799	\$52,481
Length of Stay	7.13	25.03	4.52	20.27	9.81	16.96
Number of Diagnoses	5.94	9.68	5.33	10.34	7.06	9.93
Number of Procedures	3.06	6.93	1.47	4.47	2.02	2.51

Table 2 summarizes the frequency distribution of patients within race, age, gender, and insurance categories. The percentage of patients in each category with a PSI is also included. Patients were mostly elderly, white, female, and with Medicare insurance. The elderly were disproportionately affected by Decubitus Ulcer, but this is not surprising given their fragility. Blacks have the highest incidences for all three conditions.

Table 2 Patient Demographics

	Postoperative Sepsis (n=46,843)		Infection Due to Medical Care (n=289,254)		Decubitus Ulcer (n=376,630)	
	% of Population	% with PSI	% of Population	% with PSI	% of Population	% with PSI
AGECAT						
1 (0-17)	2.95	0.87	7.29	.16	4.08	.23
2 (18-39)	8.64	0.96	26.93	.11	10.10	.63
3 (40-64)	38.77	0.99	28.24	.28	29.38	1.47
4 (65+)	49.64	1.14	37.53	.24	56.44	3.27
PAYCAT						
Medicare (M)	49.48	1.32	39.07	.29	58.31	3.18
Medicaid (D)	5.62	1.10	15.81	.19	10.96	1.54
Private (P)	39.33	0.78	36.68	.15	24.34	1.06
Self (S)	1.7	0.38	4.72	.13	3.43	.84
Other (O)	3.88	0.77	3.72	.12	2.95	1.28
RACECAT						
White (W)	55.72	0.97	52.05	.20	55.98	2.30
Black (B)	6.84	1.65	9.74	.38	10.47	3.34
Hispanic (H)	4.05	1.42	8.64	.22	6.40	2.46
Other (O)	33.39	1.04	29.57	.16	27.16	2.04
SEXCAT						
Male (M)	45.09	1.31	38.11	.26	45.24	2.19
Female (F)	54.91	0.85	61.89	.18	54.76	2.48

Looking at hospital characteristics in Table 3 shows that hospitals in the NIS sample were primarily in the South, in urban areas, and were of large bed size<sup>3</sup>. One statistic does stand out.

Postoperative Sepsis is more prevalent in hospitals in the South.

Table 3 Hospital Characteristics

	Postoperative Sepsis (n=46,843)		Infection Due to Medical Care (n=289,254)		Decubitus Ulcer (n=376,630)	
	% of Population	% with PSI	% of Population	% with PSI	% of Population	% with PSI
Discharge Quarter						
1 (Winter)	24.92	1.00	25.91	.20	26.52	2.34
2 (Spring)	25.39	1.02	25.04	.22	24.96	2.38
3 (Summer)	24.61	1.00	24.32	.20	23.94	2.27

<sup>3</sup> Bedsizes category is a relative term based on a hospital's location and teaching status. Detailed definitions can be found at the AHRQ website: [http://www.hcup-us.ahrq.gov/db/vars/hosp\\_bedsizes/nisnote.jsp](http://www.hcup-us.ahrq.gov/db/vars/hosp_bedsizes/nisnote.jsp)

4 (Fall)	25.08	1.21	24.73	.22	24.58	2.41
Hospital Region						
1 (Northeast)	20.90	0.78	19.66	0.23	22.87	2.46
2 (Midwest)	25.47	0.99	21.66	0.17	21.37	2.02
3 (South)	45.33	1.29	39.89	0.21	40.11	2.40
4 (West)	8.30	0.69	18.78	0.23	15.65	2.50
Hospital Location						
0 (Rural)	10.58	1.05	16.13	.10	13.97	2.26
1 (Urban)	89.42	1.06	83.87	.23	86.03	2.36
Hospital Teaching Status						
0 (NonTeaching)	46.48	1.15	58.46	0.17	56.24	2.42
1 (Teaching)	53.52	0.97	41.54	0.26	43.76	2.26
Hospital Bedsize						
1 (Small)	10.86	1.04	11.69	0.18	10.77	2.50
2 (Medium)	21.51	1.06	27.22	0.17	26.04	2.37
3 (Large)	67.63	1.06	61.09	0.23	63.19	2.31

### Hypotheses and Methodology

This study will look at two issues – one is the health services issue of who gets these adverse patient safety events and the second is the economic costs of the PSI. The results from part one will be used to compare the differential effects on costs based on the contributing patient and hospital characteristics.

**Hypothesis One:** The likelihood of contracting an adverse patient safety event (PSI) is not random, but systematically related to the patient’s socio-demographic characteristics, including his ability to pay and the admitting hospital’s characteristics.

**Hypothesis Two:** The presence of a PSI leads to longer lengths of stay and higher charges after controlling for other factors.

These hypotheses will be formally tested by multiple regression techniques.

## Methodology and Results for Hypothesis One

To test the first hypothesis, I estimated a logistic regression. The dependent variable is the presence of the PSI, while the independent variables were chosen based on the following sets of characteristics:

### Severity of Illness

- Number of procedures
- Number of diagnoses

### Patient Characteristics

- Gender
- Age
- Race
- Insurance type

### Hospital Characteristics

- Discharge quarter
- Hospital location
- Hospital region
- Teaching hospital
- Hospital size

The form taken is:

$$\text{Logit } Y = \beta X + e$$

Y is the “choice” variable. It equals 1 if the PSI is present and 0 if no PSI is present.

X is the vector of independent variables below. For categorical variables, the control value is underlined.

Number of diagnoses

Number of procedures

Insurance type Dummy variables (Medicare, Medicaid, selfinsured, private, other)

Gender Dummy variable (male, female)

Age category Dummy variables (child, young, middleage, elderly)

Race Dummy variables (black, white, Hispanic, other)

Discharge quarter Dummy variables (winter, spring, summer, fall)

Hospital location Dummy variable (rural or urban)

Hospital region Dummy variables (south, northeast, midwest, west)

Teaching hospital Dummy variable (teaching, nonteaching)

Hospital size Dummy variables (small, medium, large)

## Results from the Logistic Regressions

Table 4A summarizes the results from the logistic regressions. Using a young, black, self-insured female who was a patient in the winter at a small, rural, non-teaching hospital in the Midwest as the control person, the three logistic regressions showed some significant and consistent results.<sup>4</sup> As expected, the number of diagnoses and number of procedures, which proxy severity of illness, were significant and generally associated with a higher likelihood of getting the PSI; in five out of six cases, each additional diagnosis or procedure<sup>5</sup> raises the likelihood of contracting a patient safety event by 22.7% (additional procedure, Infection Due to Medical Care) to 31.4% (additional diagnosis, Infection Due to Medical Care). The one exception was that the number of procedures in the Decubitus Ulcer results was significant but had an extremely small negative impact on the likelihood of getting a PSI - just a 2% smaller likelihood of getting the PSI.

Table 4A Who gets PSIs?: Results from Logistic Regressions

Variable	Decubitus Ulcer			Infection Due to Medical Care			Postoperative Sepsis		
	Estimate	Odds Ratio		Estimate	Odds Ratio		Estimate	Odds Ratio	
Intercept	-6.535*** (0.1307)	-----		-9.165*** (0.3756)	-----		-7.826*** (0.6786)	-----	
NDX	0.236*** (0.0035)	1.266		0.273*** (0.0112)	1.314		0.271*** (0.0175)	1.312	
NPR	-0.018*** (0.0044)	0.982		0.204*** (0.0128)	1.227		0.261*** (0.0183)	1.298	
OtherIns	0.232 (0.1302)	1.262		-0.030 (0.3783)	0.971		0.812 (0.6437)	2.253	
Medicaid	0.454*** (0.1059)	1.575		0.260 (0.2807)	1.297		0.948 (0.6161)	2.580	
Private	0.048 (0.1032)	1.049		0.151 (0.2687)	1.163		0.785 (0.5904)	2.191	
Medicare	0.468*** (0.1016)	1.596		0.863** (0.2755)	2.370		1.374* (0.5953)	3.950	
Male	-0.071** (0.0225)	0.932		0.124 (0.0865)	1.132		0.285** (0.0958)	1.330	
Child	-0.924*** (0.1861)	0.397		0.543* (0.2154)	1.722		-0.427 (0.3577)	0.652	

<sup>4</sup> The health services research literature invariably reports results with odds ratios. A marginal probability table is also provided as an attachment; see table 4B.

<sup>5</sup> Number of diagnoses and number of procedures are not ideal proxies for severity of illness, but are ambiguously defined here and are interpreted as an “average” diagnosis or procedure. Given additional time and resources, it would be possible to identify various diagnoses and procedures as major or minor to better determine severity of illness.

elderly	1.062***	(0.0733)	2.892	-0.819***	(0.1676)	0.441	-1.001***	(0.2078)	0.368
Middleage	0.564***	(0.0716)	1.757	0.056	(0.1386)	1.057	-0.504**	(0.1851)	0.604
White	-0.663***	(0.0337)	0.515	-0.592***	(0.1224)	0.553	-0.691***	(0.1658)	0.501
Hispanic	-0.246**	(0.0526)	0.782	-0.286	(0.1787)	0.751	-0.126	(0.2478)	0.882
OtherRace	-0.385***	(0.0383)	0.681	-0.352*	(0.1401)	0.703	-0.081	(0.1721)	0.923
Spring	0.008	(0.0306)	1.008	0.077	(0.1179)	1.080	0.035	(0.1356)	1.035
Summer	-0.038	(0.0313)	0.963	-0.073	(0.1228)	0.929	0.002	(0.1378)	1.002
Fall	-0.010	(0.0307)	0.990	0.043	(0.1183)	1.044	0.176	(0.1314)	1.192
UrbanHosp	0.068*	(0.0344)	1.070	0.459**	(0.1603)	1.583	-0.030	(0.1622)	0.971
South	0.337***	(0.0325)	1.401	0.475**	(0.1260)	1.609	0.421**	(0.1232)	1.524
Northeast	0.350***	(0.0361)	1.418	0.333*	(0.1409)	1.396	-0.322 (*)	(0.1644)	0.725
West	-0.169***	(0.0407)	0.844	-0.351*	(0.1534)	0.704	-0.324	(0.2248)	0.723
TeachingHosp	0.029	(0.0245)	1.030	0.162	(0.0933)	1.175	-0.249*	(0.1027)	0.780
MediumSize	-0.093*	(0.0391)	0.911	-0.215	(0.1597)	0.807	0.062	(0.1779)	1.064
LargeSize	-0.150***	(0.0358)	0.861	0.076	(0.1430)	1.079	-0.145	(0.1613)	0.865

Note: Standard errors are in parentheses

\*\*\* significant at p<.0001

\*\* significant at p<0.01

\* significant at p<0.05

Insurance status produced mixed results. Neither Other insurance nor Private insurance was statistically different from self insurance. Medicaid was only significant in the Decubitus Ulcer regression, where it was associated with a 57.5% greater likelihood of getting the PSI. Medicare, on the other hand, was significant in all regressions and associated with a much greater likelihood of the patient contracting the PSI – 59.6% greater for Decubitus Ulcer, 137% greater for Selected Infection Due to Medical Care, and 295% greater for Postoperative Sepsis.

While personal characteristics were influential in the odds of getting a PSI, neither gender nor age showed consistent results across all three PSIs. Men were only slightly less likely than women to get a Decubitus Ulcer, but were 33% more likely to get Postoperative Sepsis. A child was only 39.7% as likely to get a Decubitus Ulcer as a young person, but 72.2% more likely to get a Selected Infection Due to Medical Care. An elderly person was 189% more likely to get a Decubitus Ulcer, which is not surprising due to the nature of the disease. However, it was surprising that they were less likely to get the other two PSIs - only 44% as likely to get an

Infection Due to Medical Care and 36.8% as likely to get Postoperative Sepsis. Middleage was associated with a 75.7% greater likelihood of the Decubitus Ulcer and a 40% lower likelihood of Postoperative Sepsis.

The race variable had some strikingly consistent results. In no case were blacks less likely to be affected by an adverse event than persons of other races. Compared to blacks, Hispanics had less likelihood of getting a Decubitus Ulcer (22%) and Other races had less likelihood of Decubitus Ulcer and Infection Due to Medical Care (32% and 30% less, respectively). The most striking race results were the significance of being white as opposed to black. Whites consistently are only 50% to 55% as likely as blacks to get any of these PSIs. Other literature has linked blacks to poorer health outcomes and this study finds it to be true for medical errors also.

Hospital characteristics had mixed effects on the likelihood of getting a PSI. The discharge quarter variables had no significance, refuting the belief that new doctors have an effect on quality of care.<sup>6</sup> Urban hospitals have a very slight positive effect for occurrences of Decubitus Ulcer, but a more significant effect on Infection Due to Medical Care – a 58.3% greater likelihood than rural hospitals. The hospital's region was significant. A hospital in the South was from 40% to 61% more likely to be associated with one of the PSIs and one in the Northeast was about 40% more likely to be associated with a Decubitus Ulcer or Infection Due to Medical Care than Midwestern hospitals. Patients were only 84% as likely to get a Decubitus Ulcer in a hospital in the West and 70.4% as likely to get an Infection Due to Medical Care in the West as those in a hospital in the Midwest. Neither teaching status nor hospital size seems to matter much. Teaching hospitals were associated with 22% lower likelihood of getting

---

<sup>6</sup> It is sometimes argued that new residents and interns, who start their rotations in July (summer), are more prone to make errors than more experienced doctors, but this belief is not supported by higher PSI rates for summer.

Postoperative Sepsis than non-teaching hospitals. Hospital size was only significant for Decubitus Ulcer. Medium size and Large size hospitals were very slightly less likely (9% and 14%, respectively) than small size hospitals for patients to get the Decubitus Ulcer.

In summary, severity of illness affects the chance of getting a PSI. Medicare is consistently associated with a much higher likelihood of getting the PSI. Age is a factor in whether the patient gets a PSI, but it seems to be more related to the specific PSI than to any PSI. Race is important. Whites are consistently about 50% less likely than blacks to get a PSI. All races are less likely than blacks to contract the PSI although some differences are not statistically significant. The hospital region predicts the odds of a patient getting a PSI fairly consistently. Southern and Northeastern hospitals present a higher likelihood that a patient will get a PSI.

#### Methodology and Results for Hypothesis Two

I will run 2 additional series of regressions. The first series is for informative comparisons. The model is designed to find the average effect on total charges and length of stay for patients having the PSI. I will use an OLS regression of the form:

$$Y = \beta X + e$$

1a.) Where Y is the natural logarithm of LOS

1b.) Where Y is the natural logarithm of total charges

X is the vector of variables as used in the logistic regression, plus the PSI of interest.

The second series is designed to determine the impacts on different groups through interaction variables. I will again use an OLS regression of the form:

$$Y = \beta X + e$$

2a.) Where Y is the natural logarithm of LOS

2b.) Where Y is the natural logarithm of total charges

X is the vector of variables used in the first series, plus interaction dummies which interact the presence of the PSI with each of the patient and hospital characteristics (such as: PSI \* Medicare, PSI \* Male, etc.)

### Results for Hypothesis Two: Average Effects Model

By graphing the frequency distribution of total charges (LOS) versus the distribution of the logarithm of total charges (LOS) it became clear that the semilog model was the most appropriate one for the OLS regressions. Tables 5A, 5B, and 5C summarize the impacts of each explanatory variable on the logarithm of LOS and total charges for Decubitus Ulcer, Selected Infections Due to Medical Care, and Postoperative Sepsis, respectively. Holding other variables constant, a Decubitus Ulcer added 33.9% to the length of the hospital stay and 22.5% to the total charge. Infection Due to Medical Care added 103% to length of stay and 76.3% to total charges. Postoperative Sepsis added 101.3% to length of stay and 87.3% to total charges.

Table 5A					
Average Effects of Patient Safety Indicator					
Decubitus Ulcer (TPPS03)					
Variable	LNLOS			LNCHG	
	Estimate	%change		Estimate	% change
Intercept	1.814 *** (0.006)			8.627 *** (0.009)	
TPPS03	0.292 *** (0.005)	33.88		0.203 *** (0.007)	22.45
NDX	0.032 *** (0.000)	3.22		0.036 *** (0.000)	3.70
NPR	0.064 *** (0.000)	6.59		0.190 *** (0.000)	20.96
Child	0.039 *** (0.005)	3.96		0.110 *** (0.006)	11.62
Elderly	-0.113 *** (0.003)	-10.70		0.073 *** (0.004)	7.59
Middleage	-0.075 *** (0.003)	-7.18		0.075 *** (0.004)	7.79
OtherIns	-0.005 (0.006)	-0.51		0.129 *** (0.008)	13.76
Medicaid	0.067 *** (0.005)	6.88		0.034 *** (0.007)	3.46
Private	-0.055 *** (0.004)	-5.31		0.101 *** (0.006)	10.57
Medicare	0.029 *** (0.005)	2.94		0.054 *** (0.006)	5.58
Male	-0.003 · (0.002)	-0.32		0.042 *** (0.002)	4.27
White	-0.045 *** (0.003)	-4.38		-0.022 *** (0.004)	-2.16
Hispanic	-0.044 *** (0.004)	-4.27		0.068 *** (0.005)	7.03
OtherRace	-0.033 *** (0.003)	-3.27		0.027 *** (0.004)	2.73
Spring	-0.007 ** (0.002)	-0.70		0.016 *** (0.003)	1.57

Summer	-0.007 ** (0.002)	-0.73	0.038 *** (0.003)	3.89
Fall	-0.011 *** (0.002)	-1.08	0.070 *** (0.003)	7.24
UrbanHosp	0.039 *** (0.002)	3.94	0.344 *** (0.003)	41.00
South	0.018 *** (0.002)	1.83	0.037 *** (0.003)	3.80
Northeast	0.068 *** (0.002)	7.08	0.075 *** (0.003)	7.77
West	-0.025 *** (0.003)	-2.43	0.251 *** (0.004)	28.53
TeachingHosp	0.011 *** (0.002)	1.08	0.040 *** (0.002)	4.08
MediumSize	0.004 (0.003)	0.41	0.073 *** (0.004)	7.53
LargeSize	0.014 *** (0.003)	1.37	0.131 *** (0.003)	14.02

Note: Standard errors are in parentheses

Table5B Average Effects of Patient Safety Indicator				
Infection Due to Medical Care (TPPS07)				
Variable	LNLOS		LNCHG	
	Estimate	%change	Estimate	% change
Intercept	0.402 *** (0.011)		7.616 *** (0.010)	
TPPS07	0.708 *** (0.031)	102.98	0.567 *** (0.030)	76.30
NDX	0.097 *** (0.001)	10.13	0.064 *** (0.001)	6.63
NPR	0.073 *** (0.001)	7.60	0.217 *** (0.001)	24.29
Child	0.096 *** (0.006)	10.08	0.096 *** (0.006)	10.10
Elderly	0.100 *** (0.006)	10.57	0.404 *** (0.005)	49.78
Middleage	0.066 *** (0.004)	6.82	0.357 *** (0.004)	42.94
OtherIns	0.031 ** (0.010)	3.16	0.145 *** (0.010)	15.56
Medicaid	0.087 *** (0.007)	9.12	-0.009 (0.007)	-0.88
Private	-0.035 *** (0.007)	-3.40	0.037 *** (0.007)	3.73
Medicare	0.134 *** (0.008)	14.31	0.081 *** (0.008)	8.45
Male	-0.010 ** (0.003)	-0.97	0.101 *** (0.003)	10.67
White	-0.130 *** (0.005)	-12.18	-0.049 *** (0.005)	-4.79
Hispanic	-0.092 *** (0.007)	-8.83	0.012 (0.007)	1.22
OtherRace	-0.102 *** (0.005)	-9.68	-0.042 *** (0.005)	-4.15
Spring	-0.025 *** (0.004)	-2.49	0.009 * (0.004)	0.89
Summer	-0.031 *** (0.004)	-3.05	0.027 *** (0.004)	2.74
Fall	-0.035 *** (0.004)	-3.39	0.062 *** (0.004)	6.37
UrbanHosp	0.074 *** (0.004)	7.63	0.370 *** (0.004)	44.83
South	0.028 *** (0.004)	2.82	0.036 *** (0.004)	3.72
Northeast	0.106 *** (0.005)	11.24	0.065 *** (0.005)	6.76
West	-0.086 *** (0.005)	-8.21	0.183 *** (0.005)	20.12
TeachingHosp	0.011 ** (0.003)	1.06	0.035 *** (0.003)	3.51
MediumSize	0.017 ** (0.005)	1.73	0.096 *** (0.005)	10.08

LargeSize	0.017 ** (0.005)	1.75	0.151 *** (0.004)	16.33
-----------	------------------	------	-------------------	-------

Note: Standard errors are in parentheses

Table 5C Average Effects of Patient Safety Indicator					
Postoperative Sepsis (TPPS13)					
Variable	LNLOS		LNCHG		
	Estimate	%change	Estimate	% change	
Intercept	1.440 *** (0.020)		8.882 *** (0.028)		
TPPS13	0.700 *** (0.019)	101.32	0.628 *** (0.027)	87.33	
NDX	0.046 *** (0.001)	4.74	0.025 *** (0.001)	2.56	
NPR	0.073 *** (0.001)	7.61	0.140 *** (0.001)	15.01	
Child	0.066 *** (0.013)	6.85	0.210 *** (0.019)	23.37	
Elderly	-0.012 (0.009)	-1.24	0.157 *** (0.012)	17.01	
Middleage	-0.025 ** (0.007)	-2.48	0.122 *** (0.010)	12.92	
OtherIns	-0.120 *** (0.018)	-11.29	0.194 *** (0.025)	21.42	
Medicaid	-0.032 (0.017)	-3.10	0.104 *** (0.024)	10.92	
Private	-0.133 *** (0.015)	-12.48	0.118 *** (0.021)	12.53	
Medicare	-0.062 *** (0.016)	-6.01	0.104 *** (0.022)	10.96	
Male	0.015 ** (0.004)	1.51	0.104 *** (0.006)	10.94	
White	-0.075 *** (0.008)	-7.23	0.057 *** (0.011)	5.88	
Hispanic	-0.017 (0.012)	-1.65	0.109 *** (0.017)	11.47	
OtherRace	-0.069 *** (0.008)	-6.70	0.093 *** (0.012)	9.79	
Spring	-0.006 (0.005)	-0.64	0.032 *** (0.008)	3.25	
Summer	-0.016 ** (0.005)	-1.57	0.040 *** (0.008)	4.12	
Fall	-0.019 ** (0.005)	-1.88	0.071 *** (0.008)	7.36	
UrbanHosp	-0.004 (0.007)	-0.44	0.233 *** (0.009)	26.24	
South	0.036 *** (0.005)	3.64	0.024 ** (0.007)	2.41	
Northeast	0.035 *** (0.006)	3.58	-0.006 (0.008)	-0.62	
West	-0.027 ** (0.008)	-2.62	0.050 *** (0.011)	5.10	
TeachingHosp	0.011 ** (0.004)	1.13	0.076 *** (0.006)	7.85	
MediumSize	0.004 (0.007)	0.43	0.063 *** (0.010)	6.48	
LargeSize	0.019 ** (0.006)	1.94	0.099 *** (0.009)	10.41	

Note: Standard errors are in parentheses

Other interesting results from the average effects model were that each additional procedure adds about 7% to LOS and from 15% to 24% to the total charge. Each additional diagnosis adds from 3.2% to 10.1% to LOS and from 2.6% to 6.6% to total charges. Other

Insurance adds from 13.7% to 21.4% to the total charges in comparison to the self-insured. Those with private insurance spend from 3.4% to 12.5% less time in the hospital than do otherwise-similar self-insured patients. Total charges for children average 10% to 23% higher than charges for young patients. Whites, Hispanics and Other races nearly always spend less time in the hospital than blacks, with whites having the largest differences in length of stay. Total charges at urban hospitals are always more than for rural hospitals: among other possible explanations, urban hospitals are likely to have to pay higher wages and salaries to their personnel. Total charges are on average higher for hospitals in the West (5%-28.5% greater), even though LOS tends to be shorter in western hospitals. Total charges are also higher, on average, for large size hospitals (10.4%-16.3% greater) and teaching hospitals (3.5%-7.9%), probably because they possess more technology and highly skilled workers than smaller or non-teaching hospitals.

In summary, while the magnitudes of the effects were not known beforehand, the relative impacts of these three PSIs were consistent with previous studies on the costs of the events. Postoperative Sepsis has consistently been reported as the most costly adverse event. Decubitus Ulcer was expected to be the least costly of the three events. These findings are comparable to Zhan and Miller (2003) who found Decubitus Ulcer to be the least serious of the three PSIs I used and the nosocomial infections to have much larger impacts. Their (Zhan and Miller, 2003) results for excess LOS were 3.98, 9.58, and 10.89 days, while excess charges were \$10,845, \$38,656, and \$57,727 for Decubitus Ulcer, selected infection due to medical care, and Postoperative Sepsis respectively.

## Results from Hypothesis Two: Marginal Effects Model

Tables 6A, 6B, and 6C provide the detailed results of the marginal effects regression models. The presence of a PSI in the control group (young, black, females who are self insured, do not have the PSI, and are treated in small Midwestern non-teaching hospitals) resulted in a positive effect as expected and the relative magnitudes were again consistent with a priori expectations. Decubitus Ulcer added the smallest increase to LOS (31.5%) and total charges (66.5%); Infections Due to Medical Care was second highest with a 142.3% increase in LOS and 156.2% higher total charges; while Postoperative Sepsis had the largest impact with 151.9% longer LOS and 179.5% higher total charges.

Each additional diagnosis adds less to the overall length of stay and to total charges (by about 1%) for the control group if Decubitus Ulcer is present than if it is not present. On the other hand, each additional procedure adds more to LOS in the presence of Decubitus Ulcer than in the absence of Decubitus Ulcer, by 5.6%; the relationship between number of procedures and total charges are not affected by presence of Decubitus Ulcer. Being Hispanic, male or being discharged from a hospital in the South, Northeast, West, or urban location increased the interaction between presence of Decubitus Ulcer and length of stay, while being a child, on Medicare or in a medium sized hospital greatly reduced the interaction between presence of Decubitus Ulcer and length of stay. With regard to total charges, being elderly or middle aged, or in a medium sized hospital reduced the interaction between presence of Decubitus Ulcer and charges, while Medicaid or urban or Southern location tended to heighten the impact of Decubitus Ulcers on the total charge, compared to the control group.

Table 6A

**Marginal Effects of Patient Safety Indicator**

## Decubitus Ulcer

Variable	LNLOS		LNCHG	
	Estimate	%change	Estimate	% change
Intercept	1.816 *** (0.006)		8.627 *** (0.009)	
TPPS03	0.274 *** (0.046)	31.51	0.510 *** (0.063)	66.47
PSI*NDX	-0.012 *** (0.002)	-1.20	-0.014 *** (0.003)	-1.40
NDX	0.032 *** (0.000)	3.24	0.037 *** (0.000)	3.73
PSI*NPR	0.054 *** (0.002)	5.57	0.004 (0.003)	0.41
NPR	0.062 *** (0.000)	6.39	0.190 *** (0.000)	20.93
PSI*Child	-0.255 ** (0.086)	-22.51	-0.186 (0.118)	-16.96
Child	0.040 *** (0.005)	4.11	0.112 *** (0.006)	11.85
PSI*Elderly	-0.044 (0.033)	-4.32	-0.281 *** (0.045)	-24.48
Elderly	-0.112 *** (0.003)	-10.60	0.075 *** (0.004)	7.83
PSI*Middleage	-0.007 (0.033)	-0.74	-0.143 ** (0.045)	-13.33
Middleage	-0.075 *** (0.003)	-7.19	0.074 *** (0.004)	7.73
PSI*OtherIns	n/a	...	n/a	...
OtherIns	-0.005 (0.006)	-0.47	0.129 *** (0.008)	13.74
PSI*Medicaid	-0.032 (0.024)	-3.12	0.130 *** (0.032)	13.90
Medicaid	0.066 *** (0.005)	6.78	0.031 *** (0.007)	3.15
PSI*Private	n/a	...	n/a	...
Private	-0.054 *** (0.004)	-5.28	0.100 *** (0.006)	10.56
PSI*Medicare	-0.095 *** (0.017)	-9.08	-0.011 (0.023)	-1.09
Medicare	0.030 *** (0.005)	3.03	0.054 *** (0.006)	5.51
PSI*Male	0.034 ** (0.010)	3.43	0.029 * (0.014)	2.94
Male	-0.004 * (0.002)	-0.36	0.041 *** (0.002)	4.20
PSI*White	0.020 (0.015)	2.05	0.000 (0.021)	0.04
White	-0.045 *** (0.003)	-4.39	-0.022 *** (0.004)	-2.18
PSI*Hispanic	0.067 ** (0.024)	6.90	0.002 (0.033)	0.25
Hispanic	-0.045 *** (0.004)	-4.37	0.068 *** (0.005)	7.02
PSI*OtherRace	0.010 (0.018)	1.04	0.009 (0.024)	0.93
OtherRace	-0.033 *** (0.003)	-3.29	0.026 *** (0.004)	2.67
PSI*Spring	n/a	...	n/a	...
Spring	-0.007 ** (0.002)	-0.70	0.016 *** (0.003)	1.58
PSI*Summer	n/a	...	n/a	...
Summer	-0.007 ** (0.002)	-0.71	0.038 *** (0.003)	3.89
PSI*Fall	n/a	...	n/a	...
Fall	-0.011 *** (0.002)	-1.07	0.070 *** (0.003)	6.53

PSI*UrbanHosp	0.063 *** (0.015)	6.50	0.063 ** (0.021)	6.53
UrbanHosp	0.037 *** (0.002)	3.82	0.342 *** (0.003)	40.81
PSI*South	0.103 *** (0.015)	10.87	0.049 * (0.021)	4.98
South	0.016 *** (0.002)	1.61	0.036 *** (0.003)	3.66
PSI*Northeast	0.072 *** (0.017)	7.43	0.040 (0.023)	4.08
Northeast	0.066 *** (0.002)	6.85	0.074 *** (0.003)	7.68
PSI*West	0.055 ** (0.018)	5.67	0.037 (0.025)	3.77
West	-0.025 *** (0.003)	-2.47	0.251 *** (0.004)	28.51
PSI*TeachHosp	n/a	...	n/a	...
TeachingHosp	0.011 *** (0.002)	1.13	0.040 *** (0.002)	4.09
PSI*MediumSize	-0.058 ** (0.018)	-5.64	-0.062 ** (0.024)	-6.01
MediumSize	0.006 * (0.003)	0.58	0.074 *** (0.004)	7.71
PSI*LargeSize	-0.039 * (0.016)	-3.85	-0.034 (0.022)	-3.37
LargeSize	0.015 *** (0.003)	1.52	0.132 *** (0.004)	14.15

Note: Standard errors are in parentheses

Table 6B **Marginal Effects of Patient Safety Indicator**

Variable	LNLOS		LNCHG	
	Estimate	%change	Estimate	%change
Intercept	0.4025 *** (0.011)		7.6159 *** (0.010)	
TPPS07	0.8850 *** (0.180)	142.30	0.9407 *** (0.176)	156.18
PSI*NDX	-0.0670 *** (0.010)	-6.48	-0.0482 *** (0.009)	-4.71
NDX	0.0967 *** (0.001)	10.16	0.0643 *** (0.001)	6.65
PSI*NPR	0.0917 *** (0.010)	9.61	-0.0024 (0.010)	-0.24
NPR	0.0728 *** (0.001)	7.55	0.2176 *** (0.001)	24.30
PSI*Child	0.2014 (0.147)	22.32	0.4372 ** (0.143)	54.83
Child	0.0952 *** (0.006)	9.99	0.0956 *** (0.006)	10.03
PSI*Elderly	-0.0773 (0.079)	-7.43	-0.1783 * (0.077)	-16.33
Elderly	0.1000 *** (0.006)	10.51	0.4042 *** (0.005)	49.82
PSI*Middleage	n/a	...	n/a	...
Middleage	0.0656 *** (0.004)	6.78	0.3571 *** (0.004)	42.91
PSI*OtherIns	n/a	...	n/a	...
OtherIns	0.0314 ** (0.010)	3.19	0.1446 *** (0.010)	15.56
PSI*Medicaid	n/a	...	n/a	...
Medicaid	0.0872 *** (0.007)	9.11	-0.0089 (0.007)	-0.89
PSI*Private	n/a	...	n/a	...
Private	-0.0345 *** (0.007)	-3.39	0.0365 *** (0.007)	3.71
PSI*Medicare	-0.2130 ** (0.079)	-19.19	-0.1303 (0.077)	-12.22

Medicare	0.1342 *** (0.008)	14.36	0.0811 *** (0.008)	8.44
PSI*Male	n/a	...	n/a	...
Male	-0.0099 ** (0.003)	-0.99	0.1013 *** (0.003)	10.66
PSI*White	-0.0180 (0.075)	-1.78	-0.0186 (0.073)	-1.84
White	-0.1298 *** (0.005)	-12.18	-0.0492 *** (0.005)	-4.80
PSI*Hispanic	n/a	...	n/a	...
Hispanic	-0.0923 *** (0.007)	-8.82	0.0121 (0.007)	1.22
PSI*OtherRace	0.0341 (0.093)	3.47	0.0751 (0.091)	7.79
OtherRace	-0.1018 *** (0.005)	-9.68	-0.0428 *** (0.005)	-4.18
PSI*Spring	n/a	...	n/a	...
Spring	-0.0252 *** (0.004)	-2.49	0.0089 * (0.004)	0.90
PSI*Summer	n/a	...	n/a	...
Summer	-0.0310 *** (0.004)	-3.05	0.0272 *** (0.004)	2.75
PSI*Fall	n/a	...	n/a	...
Fall	-0.0345 *** (0.004)	-3.39	0.0618 *** (0.004)	6.37
PSI*UrbanHosp	0.1203 (0.120)	12.78	0.1294 (0.117)	13.82
UrbanHosp	0.0737 *** (0.004)	7.65	0.3703 *** (0.004)	44.82
PSI*South	0.2314 * (0.093)	26.04	0.1306 (0.091)	13.95
South	0.0272 *** (0.004)	2.75	0.0361 *** (0.004)	3.67
PSI*Northeast	0.2867 ** (0.107)	33.20	0.2282 * (0.104)	25.63
Northeast	0.1057 *** (0.005)	11.15	0.0647 *** (0.005)	6.68
PSI*West	0.0172 (0.107)	1.74	0.1731 (0.105)	18.89
West	-0.0855 *** (0.005)	-8.19	0.1832 *** (0.005)	20.10
PSI*TeachHosp	-0.0391 (0.068)	-3.83	-0.0061 (0.067)	-0.61
TeachingHosp	0.0105 ** (0.003)	1.06	0.0344 *** (0.003)	3.50
PSI*MediumSize	n/a	...	n/a	...
MediumSize	0.0173 ** (0.005)	1.75	0.0962 *** (0.005)	10.10
PSI*LargeSize	n/a	...	n/a	...
LargeSize	0.0175 ** (0.005)	1.77	0.1515 *** (0.004)	16.35

Note: Standard errors are in parentheses

Table 6C **Marginal Effects of Patient Safety Indicator**

Variable	LNLOS		LNCHG	
	Estimate	%change	Estimate	%change
Intercept	1.441 *** (0.020)		8.882 *** (0.028)	
TPPS13	0.924 *** (0.102)	151.90	1.028 *** (0.144)	179.45
PSI*NDX	-0.034 ** (0.009)	-3.31	-0.032 * (0.013)	-3.19
NDX	0.046 *** (0.001)	4.76	0.025 *** (0.001)	2.57

PSI*NPR	0.018 *	(0.008)	1.78	0.026 *	(0.012)	2.58
NPR	0.073 ***	(0.001)	7.60	0.140 ***	(0.001)	14.99
PSI*Child	n/a		...	n/a		...
Child	0.066 ***	(0.013)	6.84	0.210 ***	(0.019)	23.34
PSI*Elderly	-0.098	(0.077)	-9.29	-0.181	(0.108)	-16.52
Elderly	-0.012	(0.009)	-1.22	0.158 ***	(0.012)	17.09
PSI*Middleage	-0.102	(0.068)	-9.72	-0.295 **	(0.095)	-25.51
Middleage	-0.025 **	(0.007)	-2.43	0.124 ***	(0.010)	13.20
PSI*OtherIns	n/a		...	n/a		...
OtherIns	-0.120 ***	(0.018)	-11.33	0.193 ***	(0.025)	21.30
PSI*Medicaid	n/a		...	n/a		...
Medicaid	-0.032	(0.017)	-3.17	0.103 ***	(0.024)	10.83
PSI*Private	n/a		...	n/a		...
Private	-0.134 ***	(0.015)	-12.52	0.117 ***	(0.021)	12.44
PSI*Medicare	-0.087	(0.053)	-8.32	-0.172 *	(0.074)	-15.80
Medicare	-0.061 **	(0.016)	-5.93	0.106 ***	(0.022)	11.14
PSI*Male	0.008	(0.038)	0.83	-0.092	(0.054)	-8.78
Male	0.015 **	(0.004)	1.48	0.105 ***	(0.006)	11.04
PSI*White	0.082 *	(0.040)	8.54	0.076	(0.057)	7.94
White	-0.076 ***	(0.008)	-7.30	0.056 ***	(0.011)	5.77
PSI*Hispanic	n/a		...	n/a		...
Hispanic	-0.016	(0.012)	-1.63	0.108 ***	(0.017)	11.44
PSI*OtherRace	n/a		...	n/a		...
OtherRace	-0.070 ***	(0.008)	-6.72	0.093 ***	(0.012)	9.73
PSI*Spring	n/a		...	n/a		...
Spring	-0.006	(0.005)	-0.65	0.032 ***	(0.008)	3.26
PSI*Summer	n/a		...	n/a		...
Summer	-0.016 **	(0.005)	-1.60	0.040 ***	(0.008)	4.08
PSI*Fall	n/a		...	n/a		...
Fall	-0.019 **	(0.005)	-1.90	0.071 ***	(0.008)	7.34
PSI*UrbanHosp	n/a		...	n/a		...
UrbanHosp	-0.004	(0.007)	-0.42	0.233 ***	(0.009)	26.27
PSI*South	0.049	(0.045)	4.98	0.026	(0.063)	2.60
South	0.035 ***	(0.005)	3.55	0.023 **	(0.007)	2.36
PSI*Northeast	0.146 *	(0.061)	15.76	0.015	(0.086)	1.55
Northeast	0.034 ***	(0.006)	3.46	-0.006	(0.008)	-0.62
PSI*West	n/a		...	n/a		...
West	-0.026 **	(0.008)	-2.61	0.050 ***	(0.011)	5.14
PSI*TeachHosp	0.089 *	(0.039)	9.32	0.139 *	(0.055)	14.91

TeachingHosp	0.010 * (0.004)	1.03	0.074 *** (0.006)	7.68
PSI*MediumSize	n/a	...	n/a	...
MediumSize	0.004 (0.007)	0.43	0.063 *** (0.010)	6.46
PSI*LargeSize	n/a	...	n/a	...
LargeSize	0.019 ** (0.006)	1.95	0.099 *** (0.009)	10.39

*Note: Standard errors are in parentheses*

With regard to Infections Due to Medical Care and Postoperative Sepsis, Northeastern location tended to increase the impact of both types of nosocomial infections on length of stay, and Southern location increased the impact of Infections Due to Medical Care on LOS. Medicare lowered LOS for Infections Due to Medical Care, compared to self-insured. White race raised LOS, compared to blacks, for Postoperative Sepsis, as did teaching hospital status. With regard to charges, two variables, Child and Northeast, raised considerably the impact of Infections Due to Medical Care on total charges, compared to the control groups of young patients and Midwest location. Teaching hospitals exhibit large increases to total charges, as well as to LOS for Postoperative Sepsis. It is possible that selection bias is a factor. This PSI relates to surgery, and teaching hospitals would not only perform more surgeries, but possibly new or unconventional surgeries. Patients may choose these hospitals for the unconventional surgeries, which may have inherent risk attached that has not been documented and controlled for by the PSI software in determining the risk pool.

These overall impacts from the interaction terms are summarized in Table 7. For example, the control person's total charge rises by 156% if she is afflicted with an Infection Due to Medical Care, but the total charge raises by 297% if the person is not only thus afflicted, but is also a child. Similarly, while total charge of a control person rises by 66.5% in the presence of Decubitus Ulcer, the total charge rises by an additional 23 percentage points, to 89.6%, if they are insured via Medicaid rather than self-insured. Finally, control persons with Postoperative

Sepsis suffer lengths of stay that are 152% longer than those without Postoperative Sepsis, but the length of stay penalty rises to 191.6% if the hospital is located in the Northeast, rather than the Midwest.

Table 7 Marginal Effects of PSI on LOS and TOTCHG

Variable	Decubitus Ulcer		Infection Due to Medical Care		Postoperative Sepsis	
	%Change in LOS of Control	%Change in Total Charges of Control	%Change in LOS of Control	%Change in Total Charges of Control	%Change in LOS of Control	%Change in Total Charges of Control
Mean						
PSI	31.51	66.47	142.30	156.18	151.90	179.45
PSI*NDX	29.93	64.15	126.61	144.12	143.57	170.55
PSI*NPR	38.83		165.58		156.39	186.67
PSI*Child	1.90			296.65		
PSI*Elderly		25.72		114.34		
PSI*Middleage		44.29				108.16
PSI*OtherIns						
PSI*Medicaid		89.62				
PSI*Private						
PSI*Medicare	19.57		95.81			135.30
PSI*Male	36.02	71.37				
PSI*White					173.41	
PSI*Hispanic	40.58					
PSI*OtherRace						
PSI*UrbanHosp	40.06	77.34				
PSI*South	45.81	74.75	205.39			
PSI*Northeast	41.29		222.73	221.83	191.60	
PSI*West	38.97					
PSI*TeachHosp					175.37	221.11
PSI*MediumSize	24.10	56.47				
PSI*LargeSize	26.45					

(Only those variables significant at  $p < 5\%$  are included)

## Conclusion

This study has attempted to address two important issues related to avoidable medical errors that occur in hospitals. In the first part of the study, the research attempted to determine if specific population groups were at greater or lesser risk than other population groups for contracting adverse patient safety events. In the second part of the study, the focus was on determining whether, and by how much, the presence of a PSI raised length of stay and hospital charges.

The results indicate that certain groups are more at risk than others. Blacks, in particular, are more likely to be victims of avoidable medical errors than other racial groups; this was true for all three of the PSIs examined. Seniors insured through Medicare and patients treated in Southern hospitals appeared to be more at risk than others. And, of course, patients who are sicker to begin with, in the sense that they have more secondary diagnoses and require more hospital procedures, are also at higher risk of an adverse patient safety event.

The presence of these medical errors translates into significantly longer lengths of stay and higher charges, corroborating results of other researchers. The highest avoidable cost is associated with Postoperative Sepsis. The impact of other explanatory variables on lengths of stay or charges was often sensitive to whether or not the patient had a PSI.

Since the various analyses indicated that being more severely ill to begin with, black race, being a child or elderly (on Medicare), or being treated in Southern hospitals were often associated with either a higher likelihood of being affected by a medical error or incurring higher treatment costs, it follows that prevention programs might properly target these populations especially intensively.

Future research in health services should include examining the association between blacks and the PSIs, although no significant economic costs were found. Also, it would be

useful to determine whether medical errors are uniformly distributed across hospitals, or tend to be concentrated in a small number of hospitals. For example, the policy implications from finding that medical errors are randomly distributed across hospitals are quite different from the implications that the errors are concentrated in hospitals with, say, high concentrations of poorly insured minority populations. High concentrations of medical errors might also be due to human capital deficiencies in some hospitals. Ideally, it would be very helpful to be able to link medical adverse events rates to staffing shortages or physician characteristics in individual hospitals, but such detailed analysis cannot be done with the data that are available to me. It would also be of interest to determine the degree to which the excess costs of medical errors were absorbed by insurance companies and their policy holders, taxpayers, hospitals, or the affected patients in terms of higher out of pocket payments to hospitals, lowered job productivity, or death. Finally, if reliable estimates could be developed of the total numbers of patients in American hospitals who develop nosocomial infections or Decubitus Ulcers, the results of the regression analyses could be used to estimate the total cost to the nation of these medical errors.

## References

\_\_\_ AHA Resource Center. American Hospital Association, 2004. [www.aha.org](http://www.aha.org)

\_\_\_ Hospital Infections Cost U.S. Billions of Dollars Annually. CDC Office of Communication. March 6, 2000. <http://www.cdc.gov/od/oc/media/pressrel/r2ko306b.htm>.

\_\_\_ Institute of Medicine. *To Err is Human: Building a Safer Health System*. Washington, D.C.: National Academy Press; 1999. Publication

\_\_\_ "JCAHO sounds alarm about deadly nosocomial infections; if 90,000 a year die, why are so few reported?" *Hospital Infection Control*. Feb 2003 v30 i2 p15 (1).

\_\_\_ "Monitoring Hospital-Acquired Infections to Promote Patient Safety – United States, 1990-1999." *Morbidity and Mortality Weekly Report*. March 3, 2000 v49 i8 p149.

\_\_\_ *Reducing and Preventing Adverse Drug Events To Decrease Hospital Costs*. Research in Action, Issue 1. AHRQ Publication Number 01-0020, March 2001. Agency for Healthcare Research and Quality, Rockville, MD. <http://www.ahrq.gov/qual/aderia/aderia.htm>

Migdail, M, and K. Murray. *Reducing Errors in Health Care*. Translating Research Into Practice, April 2000. AHRQ Publication No. 00-PO58. Agency for Healthcare Research and Quality, Rockville, MD. <http://www.ahrq.gov/research/errors.htm>.

Roberts, R, R. Scott, R. Cordell, S. Solomon, L Steele, L. Kampe, W. Trick, and R. Weinstein. "The use of economic modeling to determine the hospital costs associated with nosocomial infections." *Clinical Infectious Diseases*. June 1, 2003 v36 i11 p1424(9).

Stone, P, E. Larson, L Kavar. "A Systematic Audit of Economic Evidence Linking Nosocomial Infections and Infection Control Interventions: 1990-2000." *American Journal of Infection Control*. May 30, 2002 (3), 145-52.

Zhan, C and M Miller. "Excess Length of Stay, Charges, and Mortality Attributable to Medical Injuries During Hospitalization." *The Journal of the American Medical Association*. 2003; 290:1868-1874.

## ATTACHMENTS

Table 4B	Hypothesis One: Marginal Probability Effects		
	LOGIT	LOGIT	LOGIT
	Postoperative Sepsis	Infection Due to Medical Care	Decubitus Ulcer
Intercept	-0.034701	-.008564378	-0.094273
NDX	0.001203	0.000255056	0.003406
NPR	0.001158	0.000190853	-0.000259
other	0.003601	-.000027577	0.003351
medicaid	0.004203	0.000243349	0.006549
private	0.003479	0.000141053	0.000692
medicare	0.006091	0.000806548	0.006744
male	0.001265	0.000115467	-0.001017
child	-0.001893	0.000507725	-0.013325
elderly	-0.004436	-.000765103	0.015319
middleage	-0.002235	0.000052132	0.008134
white	-0.003063	-.000553032	-0.009564
Hispanic	-0.000557	-.000267322	-0.003546
OtherRace	-0.000357	-.000328673	-0.005551
spring	0.000154	0.000071708	0.000118
summer	0.000011	-.000068608	-0.000545
fall	0.000780	0.000039993	-0.000142
urban	-0.000133	0.000429297	0.000981
south	0.001868	0.000444236	0.004864
northeast	-0.001428	0.000311532	0.005041
west	-0.001437	-.000327593	-0.002443
HOSP_TEACH	-0.001104	0.000150917	0.000425
mediumSize	0.000276	-.000200773	-0.001338
largeSize	-0.000645	0.000070666	-0.002165