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RESEARCH ARTICLE

The Impact of Medical Errors on Ninety-Day Costs and Outcomes: An Examination of Surgical Patients

William E. Encinosa and Fred J. Hellinger

Objective. To estimate the effect of medical errors on medical expenditures, death, readmissions, and outpatient care within 90 days after surgery.

Data Sources. 2001–2002 MarketScan insurance claims for 5.6 million enrollees.

Study Design. The Agency for Healthcare Research and Quality Patient Safety Indicators (PSIs) were used to identify 14 PSIs among 161,004 surgeries. We used propensity score matching and multivariate regression analyses to predict expenditures and outcomes attributable to the 14 PSIs.

Principal Findings. Excess 90-day expenditures likely attributable to PSIs ranged from $646 for technical problems (accidental laceration, pneumothorax, etc.) to $28,218 for acute respiratory failure, with up to 20 percent of these costs incurred postdischarge. With a third of all 90-day deaths occurring postdischarge, the excess death rate associated with PSIs ranged from 0 to 7 percent. The excess 90-day readmission rate associated with PSIs ranged from 0 to 8 percent. Overall, 11 percent of all deaths, 2 percent of readmissions, and 2 percent of expenditures were likely due to these 14 PSIs.

Conclusions. The effects of medical errors continue long after the patient leaves the hospital. Medical error studies that focus only on the inpatient stay can underestimate the impact of patient safety events by up to 20–30 percent.

Key Words. Medical errors, patient safety, expenditures

The Committee on the Quality of Health Care in America was established in 1998 by the Institute of Medicine (IOM), and its first report estimated that between 44,000 and 98,000 Americans die each year due as a result of medical mistakes, with an associated cost of $17–$29 billion (see *To Err Is Human: Building a Safer Health Care System*, Kohn et al. 2000). It is now 8 years after the IOM report and patient safety rates across the country remain high despite modest improvements in overall quality. Of the 40 core measures tracked by the "National Healthcare Quality Report" (2006), 26 showed improvements, two showed deterioration, and 12 showed no change between 2005 and 2006. However, the pace of change remains constant at a modest annual rate of improvement of 2.3 percent in overall quality. And, for the specific case of patient safety quality, the rate of adverse events declined by only 1 percent between 2000 and 2005 ("National Healthcare Quality Report 2007"). This is far from the 50 percent reduction in medical errors that the IOM ambitiously recommended over a 5-year period.

While there are many technical barriers to improving patient safety, some of the main barriers occur at the systems level (Wachter 2004; Pronovost, Miller, and Wachter 2006). One modest step toward increasing progress at the systems level is the development of a clear business case for system-wide investments in patient safety. Indeed, a strong business case is just now beginning to be made in the literature (Zhan and Miller 2003; Dimick et al. 2006; Needleman et al. 2006; Zhan et al. 2006; Gross et al. 2007). However, a recent meta-analysis of the literature by Schmidek and Weeks (2005) suggests that more research is needed particularly on the potential returns to patient safety interventions.

A few very recent papers have addressed this issue at the national level. In one of the first papers on the topic, Zhan and Miller (2003) estimated that national costs attributable to 18 types of adverse events in the hospital totaled $4.6 billion in 2000. Zhan et al. (2006) found that, among Medicare patients, two thirds of the $300 million extra costs due to five adverse events were not covered by Medicare in 2002. This reveals that a reduction in medical errors could result in potentially large cost savings for hospitals. Similarly, Needleman et al. (2006) found that improving nurse staffing ratios to reduce adverse events could avoid between $2.6 and $6.9 billion in 2002 costs.

These national studies are an improvement over older cost studies cited in the IOM report, which are based on small samples in three states (Johnson et al. 1992; Thomas et al. 1999, 2000). However, recent studies also have limitations. For example, all three studies (Zhan and Miller 2003; Needleman et al. 2006; Zhan et al. 2006) only examine hospital costs and outcomes occurring within the initial hospitalization. Not included were postdischarge events like death, readmissions, ER visits, physician visits, and outpatient prescriptions, which may all add significantly to the total episodic costs of patient safety events.

Address correspondence to William E. Encinosa, Ph.D., Center for Delivery, Organization and Markets, Agency for Healthcare Research and Quality, 540 Gaither Road, Rockville, MD 20850; e-mail: william.encinosa@ahrq.hhs.gov. Fred J. Hellinger, Ph.D., is also with the Center for Delivery, Organization and Markets, Agency for Healthcare Research and Quality, Rockville, MD.

Second, not only do these studies fail to calculate the costs of postdischarge events such as readmissions, but they also treat readmissions as if they were initial admissions because they apply their analyses to all hospital discharges. It is more appropriate to measure patient safety events as occurring only in an index surgery and then following their costs in subsequent readmissions. Grouping readmissions with index admissions can bias cost estimates because readmissions may be caused by patient safety events occurring during the index admission. In fact, the potential for this bias to occur can be large. In our data we find that among 92,640 surgery patients with 122,875 hospital admissions in 2002, only 77 percent of these admissions were index surgeries. The remaining 23 percent were either readmissions or medical hospitalizations without surgery. Unfortunately, the aforementioned studies incorrectly treat these 23 percent of admissions as if they were index admissions, biasing any cost estimate of patient safety events.

Third, these studies use a limited measurement of inpatient costs. For example, they only include the hospital costs of the initial stay. They do not include the physician costs of the initial hospital stay. Moreover, these papers estimate hospital costs using hospital-level cost-to-charge ratios applied to patient-level charges. This can lead to imprecise estimates of costs. It is preferable to examine transacted payments rather than hospital costs because hospital costs are to a large extent an artifact of accounting convention and historical accident. Indeed, many older hospitals have depreciated their facilities and thus do not report capital costs related to their facilities even though the economic cost of their facilities is not zero. Actual transacted payments from insurers are not only more accurate than costs, but they are often much higher than hospital costs. Indeed, the private payer payment-to-cost ratio for all hospitals was 1.18 in 2003 (MedPAC 2005). Moreover, as Schmidek and Weeks (2005) emphasize, often the business case for patient safety must be made—not from the point of view of the hospitals—but from the view of the purchasers (insurers), because they are the ones who have the most leverage to stimulate hospitals to enhance patient safety. Thus, more studies need to examine costs in terms of insurer-transacted payments, not only hospital costs.

In this paper, we address these limitations using national insurance claims data with transacted payments from insurers. Moreover, to capture the full episodic costs of patient safety problems, we track patient outcomes and utilization for 3 months after the patient safety event. We include all hospital and readmissions payments, physician payments, outpatient payments, and prescription drug payments. We find that the costs of patient safety events are considerably higher when we include postdischarge costs following the initial hospitalization.

DATA AND METHODS

Data

Our source of data is the 2001–2002 MarketScan Commercial Claims and Encounter Database, which contains claims data for inpatient care, outpatient care, and prescription drugs for 5.6 million enrollees in employer-sponsored benefit plans for 45 large employers in all 50 states. This database includes about 4 percent of all employer-sponsored enrollees in the United States. We examine all medical claims incurred within 90 days after the surgery admission date. The unit of observation is any adult, nonelderly major surgery admission between March 1, 2001, and October 1, 2002, which did not follow another major surgery admission within the previous 90 days for that patient. We have a total of 161,004 observations. Only 4 percent of patients contributed more than one surgery observation.

Potentially Preventable Adverse Medical Events

We examine 14 potentially preventable adverse medical events defined by the Patient Safety Indicators (PSIs) methodology as developed by the Agency for Health Care Research and Quality (http://www.qualityindicators.ahrq.gov/psi_overview.htm). Because some patient safety events are rare, our sample size is not large enough to examine some of the PSIs individually. As a result, we combine the 14 PSIs into seven groups. The groups and their PSIs are (1) *Technical Problems*: anesthesia complication, accidental puncture or laceration, foreign body left in, iatrogenic pneumothorax, and transfusion reaction; (2) *Infections*: infection due to medical care, sepsis; (3) *Pulmonary and vascular problems*: pulmonary embolism and deep vein thrombosis; (4) Acute respiratory failure; (5) *Metabolic problems*: Physiologic and metabolic derangements; (6) *Wound problems*: hemorrhage/hematoma, wound dehiscence; and (7) *Nursing-sensitive events*: postoperative hip fracture and decubitus ulcer.

Statistical Methods

Matching. This study assembles a matched sample of cases and controls that are then used to: (1) estimate the contribution of each of the seven PSI groups on each of three binary outcomes; and (2) estimate the contribution of each of the seven PSI groups on five categories of (log) costs. We create the matched sample using a propensity score matching method. As can be seen in Table 2, the 4,140 surgeries with at least one patient safety event in the raw data have different characteristics than the 156,864 surgeries in the raw data that had none of the patient safety events. Using the *psmatch2* routine in *Stata* 9.2, we match 4,140 of the 156,864 surgeries without events to the 4,140 surgeries with patient safety events, forming a "Matched Sample" with 8,280 observations (4,140 PSI cases + 4,140 matched non-PSI cases). To do this, we first create the propensity score with a logit regression of the probability of any of the seven PSI groups occurring, controlling for the 32 covariates of Table 2 and fixed effects for 92 collapsed diagnosis-related groups (DRG) groups. Next, using the nearest-neighbor method (Becker and Ichino 2002), we create the matches by balancing propensity scores across the 32 covariates and 92 DRG groups. No observations lacked a common region of support (Becker and Ichino 2002). As can be seen in Table 2, the non-PSI cases and the PSI cases in the Matched Sample now have the same characteristics (within a 95 percent level of statistical significance) for all the covariates except for "organ transplants" and "deficiency anemias." The average absolute value of the bias in the covariates between PSI and non-PSI cases was reduced from 19.2 to 4.1 due to the matching.[1]

The 32 covariates in Table 2 used to risk adjust and match PSI cases include 20 collapsed chronic condition variables derived from 29 chronic conditions developed by Elixhauser et al. (1998) in the AHRQ Comorbidity Software. Baldwin et al. (2006) have shown that these are the best performing comorbidity measures. We also include the following clinical variables to control for potential confounding effects of patient severity, age, sex, an indicator for emergency room admission, and an indicator for an organ transplant. Next, to control for demand-side factors that may influence the patient's degree of utilization and costs, we control for the type of the health plan (health maintenance organizations [HMO], which is either a capitated HMO or a capitated point-of-service plan) and for whether the patient is an hourly wage worker (versus salaried), which may proxy for low income. The costs of PSI events should decline with HMO enrollment and low income because this a segment of the population that spends less on health care. Because we pool data from 2 years, we also include an indicator for year 2002 to control for any time trend. Finally, to control for market characteristics, we include region fixed effects and the county HMO penetration rate from InterStudy. The postdischarge costs of PSI events and readmissions should decline with HMO penetration due to better postoperative outpatient care under HMOs spilling over to the rest of the market.

Outcomes. After the matching, we use logit regressions on the Matched Sample to predict the probability of an outcome under each of the seven PSI groups, controlling for the 32 covariates of Table 2. The binary outcomes are (1) 90-day in-hospital death, (2) 90-day readmission with a postoperative problem, and (3) 90-day outpatient visit with a postoperative problem. We use 44 postoperative conditions to identify readmissions and outpatient visits that are most likely related to problems with the index surgery. The 44 postoperative conditions examined are based on an AHRQ list of 44 of the 260 conditions in the 2005 AHRQ Clinical Classification Software (CCS), which groups all ICD-9 diagnosis codes into 260 mutually exclusive diagnosis categories (http://www.hcup-us.ahrq.gov/toolssoftware/ccs/ccs.jsp). A list of the 44 conditions can be found in Encinosa et al. (2006). *Readmissions* refer to any overnight stay at an inpatient hospital beginning within 90 days after the index discharge. *Outpatient visits* include postoperative 1-day visits to an inpatient hospital, outpatient hospital, ambulatory surgery center, or emergency room, as well as office visits or home health care visits. To estimate the "excess rates" of the three outcomes that are due to each of the PSI groups, we first predict the outcome's rate assuming every surgery had an adverse event occur from that PSI class, and then predict the outcome's rate assuming every surgery had no adverse event from any of the seven PSI groups. The difference between the two rates is the excess rate due to that PSI class. The standard errors of the excess rates are computed with 1,000 bootstrapping replications.

Expenditures. Next, linear regression analysis on the Matched Sample is used to examine the relationship between PSIs and the natural logarithm of 90-day costs. Expenditures are transacted prices, including all hospital, physician, outpatient, and drug payments. We adjust all payments for the local wage rate to control for variations in medical prices across markets. After the regressions, the log of expenditures is then retransformed into dollars using the Duan smearing estimator to adjust for the bias arising under the log-retransformation (Duan 1983).

We run five separate regressions, one on each category of costs: (1) total 90-day expenditures, (2) index hospital expenditures (including physician inpatient payments), (3) 90-day readmission expenditures, (4) 90-day outpatient expenditures, and (5) 90-day outpatient drug expenditures. All regressions were run on the Matched Sample except for the readmission and outpatient expenditure regressions, which were performed on the subsets of the Matched Sample that had positive expenditures for readmissions and outpatient visits, respectively. Almost all of the Matched Sample used outpatient drugs, so the entire Matched Sample was used in the drug regression. As in the outcome regressions, we consider only readmissions and outpatient visits with the 44 postoperative conditions. To estimate the "excess total payments" due to each of the PSI groups, we first predict the payment assuming every surgery had that PSI class occur, and then predict the payment assuming every surgery had none of the seven PSI groups occur. The difference between the two payments is the excess payment due to that PSI class. To compute "excess payment" for individual categories, like readmissions, we multiply the predicted payments among the readmissions by the predicted probability of readmission found in the outcome regressions above. We do this by PSI and non-PSI. The difference is the "excess payment." The standard errors of the excess payments are computed with 1,000 bootstrapping replications.

RESULTS

Unadjusted Outcomes and Costs

During the study period, 4,140 (2.6 percent) of the 161,004 adult major surgeries had at least one of the 14 potentially preventable adverse medical events. About 5.6 percent of the 4,140 surgeries with PSI events had more than one PSI. In the non-risk-adjusted rates of Table 1, surgeries with PSIs had a 90-day death rate of 6.3 percent, compared with 0.6 percent for surgeries without PSIs. The 90-day readmission rate for surgeries with PSIs was 15.0 percent, compared with 5.5 percent for those without PSIs. These were readmissions with any of the 44 postoperative conditions. Not shown, the general 90-day readmission rate for any type of readmission was 23.3 percent for PSI events and 10.2 percent for surgeries without PSI events.

Total 90-day costs for surgeries with PSIs were $66,879 on average, versus $18,284 for surgeries without PSIs. Not shown, over the 90 days, surgeries with PSIs averaged 21.5 inpatient days, with 5.3 of these days occurring postdischarge. In contrast, surgeries without PSIs averaged 5.1 days, with 1.0 of these days occurring postdischarge. The postoperative acute respiratory failure PSI was the most expensive of the seven patient-safety event classes,

Table 1: Unadjusted 90-Day Expenditures and Outcomes for Patient Safety Events

	Number of Surgeries	*Total Payments*	*Hospital Payments (Index Visit)*	*Read-mission Payments*	*Outpatient Visit Payments*	*Drug Payments*	*Death Rate (%)*	*Read-mission Rate (%)*
No patient safety event	156,864	$18,284	$15,563	$1,126	$1,064	$532	0.6	5.5
Had a patient safety event	4,140 (2.6%)	66,879	54,968	7,115	3,883	913	6.3	15.0
Patient safety events by class:								
Technical Problems: anesthesia complication, accidental puncture or laceration, foreign body left in, iatrogenic pneumothorax, transfusion reaction	669 (0.4%)	26,199	22,732	1,639	1,269	560	1.8	8.4
Infections: infection due to medical care, PO sepsis	587 (0.4%)	86,833	69,096	11,232	5,395	1,110	7.2	20.1
Pulmonary and Vascular Problems: pulmonary embolism & deep vein thrombosis	1,212 (0.8%)	50,911	41,840	4,513	3,464	1,094	4.1	14.9
Acute Respiratory Failure	1,392 (0.9%)	106,370	88,059	12,274	5,294	742	12.0	17.4
Metabolic Problems: physiologic and metabolic derangements	76 (0.05%)	77,885	68,585	3,495	3,202	2,603	6.6	19.7
Wound Problems: hemorrhage/hematoma, PO wound dehiscence	282 (0.2%)	36,447	30,935	2,767	2,060	684	1.8	9.9
Nursing-Sensitive Events: PO hip fracture, PO decubitus ulcer	168 (0.1%)	58,237	46,859	6,592	3,917	869	5.4	13.7

Means are reported. Patient safety rates are in parentheses. Payments are in 2002 dollars. Readmissions and outpatient care include only those visits with any of 44 PO conditions. Adverse events by class do not sum to the total because 236 patients had multiple events.

Source: 2001–2002 MarketScan Employer Claims Data for 5.6 million covered lives.

PO, postoperative.

costing $106,370 over the 90-day period, and had the highest 90-day death rate, 12 percent. It also had the highest average cost of readmission, $12,274, even though the infection PSI class had the highest readmission rate, 20 versus 17 percent for respiratory failure. However, the most expensive PSI class in terms of outpatient visit costs was the infection PSI class ("infection due to medical care" and "sepsis"), with $5,395 in 90-day outpatient payments. The most expensive PSI class in terms of outpatient drug costs was "physiologic and metabolic derangements," with $2,603 in 90-day outpatient drug payments.

Adjusted Outcomes and Costs

In Table 2, we find that the surgeries with PSIs had considerably higher rates of comorbidity than the non-PSI events in the raw sample. Thus, many of the cost and outcome differences in Table 1 may be due to differences in patient characteristics. So, in Table 3, we present logit regression estimates of odds ratios for patient outcomes after PSI events, controlling for patient characteristics after matching the 4,140 PSI surgeries to 4,140 non-PSI surgeries with similar characteristics.

Deaths Due to Patient Safety Events. Infections and respiratory failure were the two PSIs with the highest adjusted odds ratios for death in Table 3. Surgeries with preventable infections had 2.16 times higher odds of death than surgeries without such infections, and surgeries with respiratory failure had 3.74 times higher odds of death than surgeries without respiratory failure. In Table 4, we estimate that the excess 90-day death rate due to respiratory failure was 6.7 percentage points. That is, not shown, the adjusted death rate for non-PSI events was 3.0 percent, compared with an adjusted death rate of 9.7 percent for respiratory failure. For infection, the excess 90-day death rate was 3.1 percentage points. Overall, in Table 4, five of the seven PSI classes had statistically significant positive excess death rates due to the PSI, ranging from 0.5 to 6.7 percentage points. Two PSI classes, technical problems and wound problems, had no statistically significant excess death rate.

Readmissions Due to Patient Safety Events. Infections, metabolic problems, and respiratory failure were the three PSI classes with the highest adjusted odds ratios for 90-day readmission in Table 3. Infections had 87.7 percent higher odds of readmission, metabolic problems had 70.2 percent higher odds of readmission, and respiratory failure had 46.9 percent higher odds of

Table 2: Descriptive Statistics for 2001–2002 Surgeries with and without Patient Safety Events

	No PSI		*PSI*
Variables	*Raw Sample*	*Matched Sample*	*Raw Sample*[†]
Patient characteristics			
In an HMO Plan	0.267	0.218	0.222
Hourly wage worker	0.259	0.342	0.321
Female	0.655	0.518	0.528
Mean age (SD)	44.7 (14.6)	49.6 (13.9)	49.4 (14.0)
Emergency admission	0.122	0.213	0.220
Organ transplant	0.004	0.019	0.011*
Year 2002	0.588	0.614	0.616
Chronic conditions			
Congestive heart failure	0.011	0.082	0.074
Valvular disease	0.015	0.046	0.045
Peripheral vascular disease	0.017	0.060	0.055
Hypertension	0.088	0.114	0.117
Paralysis	0.004	0.023	0.023
Other neurological disorders	0.008	0.049	0.049
Chronic pulmonary disease	0.030	0.065	0.062
Diabetes	0.046	0.078	0.079
Diabetic complications	0.009	0.029	0.025
Hypothyroidism	0.015	0.010	0.011
Renal failure	0.011	0.078	0.075
Liver disease	0.006	0.022	0.022
Metastatic cancer	0.018	0.045	0.047
Tumor without metastasis	0.031	0.071	0.069
Rheumatoid arthritis	0.011	0.038	0.040
Obesity	0.013	0.010	0.011
Weight loss	0.003	0.026	0.030
Electrolyte disorders	0.018	0.070	0.067
Deficiency anemias	0.027	0.042	0.051*
Depression/drug abuse	0.013	0.019	0.024
Market characteristics			
HMO penetration (SD)	0.204 (0.142)	0.213 (0.144)	0.215 (0.140)
Northeast	0.124	0.124	0.129
North Central	0.301	0.341	0.339
South	0.451	0.434	0.422
West	0.124	0.101	0.110
N	156,864	4,140	4,140

The matched sample consists of all 4,140 PSI events in the raw sample, along with 4,140 non-PSI events matched to the PSI events by propensity score based on the covariates of this table in addition to 92 DRG classes.

*Outcome rate under the PSI case is significantly different from the rate under the matched non-PSI cases at the 95% level.

[†]All rates under PSI cases are significantly different from the rate under the raw sample non-PSI cases at the 95% level, except for obesity.

DRG, diagnosis-related groups; HMO, health maintenance organization; PSI, Patient Safety Indicator; SD, standard deviation.

Table 3: Estimated Odds Ratios for 90-Day Outcomes after Patient Safety Events

Variables	*In-Hospital Death*	*Readmission with PO Condition*	*Outpatient Visit with PO Condition*
Patient safety events			
Technical problems	0.913	0.893	1.065
Infections	2.160***	1.877***	2.851***
Pulmonary and vascular problems	1.184	1.363***	2.090***
Acute respiratory failure	3.744***	1.469***	1.858***
Metabolic problems	2.137	1.702*	1.456
Wound problems	0.689	0.984	1.147
Nursing sensitive events	1.480	1.125	1.027
Patient characteristics			
HMO plan	0.926	0.960	0.833***
Hourly wage worker	1.109	1.204***	0.960
Female	0.769**	0.910	0.998
Age 18–32	—	—	—
Age 33–43	0.830	0.885	1.317***
Age 44–52	1.604*	1.088	1.610***
Age 53–59	2.176***	1.066	1.556***
Age 60–64	2.472***	0.937	1.609***
Emergency admission	2.079***	1.279***	1.677***
Organ transplant	0.945	2.982***	1.424
Year 2002	1.824***	1.105	0.868***
Market characteristics			
HMO penetration	0.394**	1.185	1.545**
Northeast	—	—	—
North central	0.593***	1.143	0.923
South	1.035	1.073	0.841*
West	0.987	0.949	0.688***
20 chronic conditions	Present	Present	Present

Based on logit regressions over the matched sample with $N = 8{,}280$. Readmissions and outpatient care include only those visits with any of 44 PO conditions.

***, **, *Significantly different from one at the 99%, 95%, 90% level. Standard errors are available from the authors.

HMO, health maintenance organization; PO, postoperative.

readmission. In Table 4, we estimate that the excess readmission rate due to infection was 7.7 percentage points (the adjusted readmission rate for non-PSI events was 11.1 percent, compared with an adjusted readmission rate of 18.8 percent for infection). For metabolic problems, the excess readmission rate was 6.3 percentage points. For respiratory failure, the excess readmission rate was 4.3 percentage points. Overall, in Table 4, four of the seven PSI classes had statistically significant positive excess readmission rates due to the PSI,

Table 4: Estimated Excess 90-Day Outcomes and Payments Due to Patient Safety Events

Patient Safety Event Class	*Excess In-Hospital Death Rate*	*Excess Readmission Rate*	*Total Excess Payments and the Share of All Payments That Are Excess*		*Excess Index Hospitalization Payments (Excess Payment to Physician)*	*Excess Readmission Payments*	*Excess Outpatient Payments*	*Excess Drug Payments*
Technical problems	– 0.2%	– 1.0%	$646	2.8%[a]	$1,407	– $616	– $97	– $48
	(0.8)	(1.0)	(1,285)		($238)[b]			
Infections	3.1%***	7.7%***	19,480***	42.0%	15,674	2,594	1,047	165
	(1.3)	(2.9)	(904)		(492)			
Pulmonary and vascular problems	0.5%**	3.4%***	7,838***	24.8%	6,533	659	373	273
	(0.2)	(1.4)	(500)		(–19)			
Acute respiratory failure	6.7%***	4.3%***	28,218***	52.0%	25,828	1,702	631	57
	(2.7)	(1.4)	(1,170)		(1,325)			
Metabolic problems	3.0%*	6.3%*	11,797***	31.8%	11,536	288	– 117	90
	(1.5)	(4.6)	(2,015)		(1,186)			
Wound problems	– 0.9%	– 0.1%	1,426	5.8%	1,285	109	54	– 22
	(2.2)	(1.9)	(1,908)		(2)			
Nursing-sensitive events	1.3%**	1.2%	12,196***	32.9%	11,657	484	40	15
	(0.6)	(3.0)	(1,367)		(62)			

Bootstrapped standard errors for totals on the left three columns are in parentheses. The mean in each of the four columns on the right is averaged over the subset of surgeries that had the given type of postoperative visit in that column.

[a]The percentage of the PSI class's total payments that are excess payments due to patient safety.

[b]The amount of the excess index hospitalization payment paid to the physician due to the PSI.

***, **, *Significantly different from zero at the 99%, 95%, 90% level.

PSI, Patient Safety Indicator.

ranging from 3.4 to 7.7 percentage points. Technical problems, nursing-sensitive problems, and wound problems had no statistically significant excess readmission rate.

Outpatient Visits Due to Patient Safety Events. In Table 3, infections had 2.9 times higher odds of a 90-day outpatient visit with a postoperative condition, pulmonary and vascular problems had 2.1 times higher odds of an outpatient visit with problems, while respiratory failure had 85.8 percent higher odds of an outpatient visit with problems. Not shown in Table 4, the excess outpatient visit rate was 18.5 percentage points for infections, 14.1 percentage points for pulmonary and vascular problems, and 12.0 percentage points for respiratory failure. The other four PSI classes had no statistically significant excess outpatient visit rate.

Expenditures Due to Patient Safety Events. In Table 4, we simulate excess 90-day expenditures due to patient safety events from log-linear regression estimates (not shown) for patient expenditures after PSI events, controlling for patient characteristics after matching the 4,140 PSI surgeries to 4,140 non-PSI surgeries with similar characteristics. From Table 4, overall adjusted excess payments for the seven PSI classes ranged from $646 to $28,218 in 2002 dollars. Respiratory failure resulted in the largest of the excess payments, $28,218. This was due to the fact that respiratory failure had the highest excess payments during the index hospitalization, $25,828. However, infections had a higher adjusted readmission rate (18.8 percent) than respiratory failure (15.4 percent), and had higher adjusted excess costs of readmissions ($2,594 versus $1,702). Recall that this differs from Table 1, where respiratory failure had higher unadjusted readmission costs than did infections.

In fact, the infection PSI class had the largest adjusted excess postdischarge expenditures in Table 4, $3,806 (where $2,594 was due to readmissions, $1,047 to outpatient visits, and $165 to drugs). Respiratory failure resulted in the second highest excess postdischarge expenditures, $2,390. Excess postdischarge payments made up 20 percent of all excess payments under infections. That is, 80 percent of the excess payments due to infection were incurred during the index hospitalization. Over all seven PSI classes, the proportion of excess payments that were incurred postdischarge ranged from 4 to 20 percent.

While infections had the highest excess payments for both readmissions and outpatient visits, pulmonary and vascular problems had the highest excess 90-day outpatient drug expenditures, $273. Recall from Table 1 that metabolic problems had the largest unadjusted drug expenditures. However, this difference is eliminated once we risk adjust drug costs in Table 4. Essentially, 70 percent of the patients with physiologic and metabolic derangements were diabetics, compared with only 7 percent of all patients with safety events. Thus, diabetes accounted for this high drug cost, not the physiologic and metabolic derangement patient safety event.

Overall, in column 3 of Table 4, 52.0 percent of all 90-day payments for surgeries with respiratory failure were excess payments due to the actual respiratory failure PSI. This was the largest fraction of total payments attributed to a PSI. The next largest was infections, accounting for 42 percent of payments. The lowest share was 2.8 percent for technical problems.

In Table 4 we also tease out the parts of the excess PSI payments of the index hospitalization that were excess 90-day payments made to the physicians. Excess payments to physicians due to patient safety events ranged from −$19 for pulmonary and vascular problems to $1,325 for respiratory failure. However, in terms of excess physician payments as a percentage of the total excess payments for the index hospitalization, technical problems had the highest rate, where 17 percent of excess index payments due to the PSI went to the doctor ($238 of $1,407).

Finally, because most recent papers on patient safety costs do not include either physician costs or postdischarge costs, they underestimate the true costs of patient safety events. To calculate the magnitude of this underestimation, we combine the costs results from Table 4 and find that the excess payments for infections increase by 28 percent when physician payments and all postdischarge payments are added to the index hospital payment ([$19,480–($15,674–$492)]/[$15,674–$492]). Similarly, by including physician costs and all postdischarge costs, excess payments increase by 20 percent for pulmonary and vascular problems, 15 percent for respiratory failure, 14 percent for metabolic problems, 11 percent for wound problems, and 5 percent for nursing-sensitive events. However, not including physician costs and all postdischarge costs results in an overestimate of excess costs for technical problems by 45 percent (because technical problems have systematically lower postdischarge costs).

Discussion

There are many reasons to reduce medical error rates—reasons based on professional ethics, oversight by regulatory and accrediting bodies, tort liability, and consumer expectations. In addition, there is also a business case emerging for the reduction of patient safety events. This is of particular interest now that Medicare will stop reimbursing hospitals for the extra costs of eight patient safety events beginning in October 2008. At that time, hospitals will have to revisit and re-evaluate their business case for increasing investments in patient safety improvements. One vital component of the business case is an accurate estimate of the potential returns to patient safety interventions. In this paper, we present one of the most complete estimates of the episodic cost savings from reducing patient safety events. Most papers that estimate the cost of medical errors only examine the initial hospitalization in which the medical error occurred. However, much can happen postdischarge. We find that the death rate increases by 50 percent over 90 days once the patient leaves the hospital. The 14 patient safety events were responsible for 11 percent of all 90-day deaths after major surgery. Moreover, the 90-day readmission rate was 6 percent after major surgery. We find that 2 percent of all these readmissions were due to the 14 PSIs. While the initial hospital stay with a PSI involved a 16.2-day length of stay on average, readmissions caused total days to increase 33 percent to 21.5 days over the 90-day period. Thus, previous studies only examining the initial stay would have substantially underestimated overall resource use (90-day length of stay) among PSI patients by 25 percent.

We find that the costs of patient safety events are considerably higher when we address all of these postoperative costs following the initial hospitalization. In fact, for excess payments due to the infections PSI class, the total excess payments during the entire 90-day episode are 28 percent larger than the excess payments incurred during the initial hospitalization. This large difference in the return on patient safety could make many interventions much more cost-effective than previously thought. For example, Needleman et al. (2006) found that increasing the RN/LPN mix to the 75th percentile and raising the number of licensed nurse hours to the 75th percentile saved $6.9 billion in 2002 costs by reducing adverse events, ignoring physician costs and postdischarge costs. By this estimate, the investment is not cost-effective for hospitals; the cost-savings would need to be 23 percent higher for the hospital to break-even on the investment. It is quite possible that the *postdischarge* cost savings achieved by reducing adverse events might just be enough for the hospital to break-even on the investment in nursing.

For the 14 patient safety events we examine, there are potentially large national costs savings from reducing these events. We have a 4 percent sample of all privately insured major surgeries in the United States and we extrapolate our results to the national level. Among the nonelderly privately insured population in the United States, we estimate that 11 percent of 90-day deaths (2,806) were due to these 14 PSIs in 2002, 2 percent of 90-day readmissions (3,519) with postoperative conditions were associated with these 14 PSIs, and 2 percent of all 90-day expenditures after major surgery ($1.47 billion) were attributable to the 14 PSIs. These are rough estimates because the MarketScan database is not a random sample of the privately insured in the United States (Medstat 2002). Indeed, the MarketScan database has disproportionately more workers in the southern United States and fewer workers in the West.

Recall that these potentially preventable adverse medical events are based only on 14 measurable patient safety indicators. Thus, there may be many more preventable safety events (as well as near misses) that occurred but that were not included in our analyses, such as medication errors. In fact, we do not consider drug-related errors, diagnostic errors, and errors in choice of therapy, all of which accounted for 12 percent of surgical errors in the Colorado–Utah study underlying the IOM report (Gawande et al. 1999). Moreover, we do not include nonmedical costs, such as days of lost work due to patient safety events. Thus, our expenditure results are an underestimate of all the expenditures attributable to all preventable adverse events.

However, we may be overestimating expenditures attributable to the 14 PSIs because our risk adjustors are not comprehensive. Recent research shows that adding "present at admission" diagnosis variables and laboratory data to our risk adjustors would increase the mean C-statistic of predicting death from 0.79 to 0.86. Adding clinical data such as vital signs and blood cultures would increase the C-statistic to 0.88 (Pine et al. 2007). Similar improvements have been found in the C-statistic for predicting the PSIs in work by the same authors (Jordan et al. 2007). Future research should examine how such data augmentations to improve risk adjusting would affect the estimate of costs attributable to the PSIs.

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Note

1. The bias is the difference in the sample means between PSI and non-PSI cases as a percentage of the square root of the average of the sample variances in the PSI and non-PSI cases. See Rosenbaum and Rubin (1985).

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Appendix SA1: Author Matrix.

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