Do Patient Safety Events Increase Readmissions?

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Objective: Adverse safety events in the hospital could impose extra costs not only due to longer stays and corrective treatments, but also due to deaths and readmissions. The effects of safety events on readmissions have rarely been analyzed. Large, all-payer and all-diagnosis databases permit new tests. This study will simultaneously test the effects of safety events on risks of deaths and readmission.

Study Design: The population is a selection of almost 1.5 million adult surgery patients initially treated in 1088 short stay hospitals. These are patients at risk for at least 1 of 9 types of patient safety event, as specified in software in the public domain from the Agency for Healthcare Research and Quality. The main data sources are 7 statewide databases of hospitalizations in 2004, maintained by Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project. We control for many factors affecting readmission or death, particularly the severity of illness, chronic comorbidities, age, and payer group. Separate models are used for each type of safety event and a composite model is used for any safety event.

Principal Findings: Among the patients at risk for any of the patient safety events, 2.6% had at least one safety event. The 3-month readmission rate was about 17% for those with no safety event, but about 25% when a safety event was recorded. The corresponding rates for readmission within 1 month were 11% and 16%. The in-hospital death rate was 1.3% with no safety event, but 9.2% with a safety event. After risk adjustment, the relative risk of readmission within 3 months was about 1.20 ($P < 0.01$), ranging from 1.14 to 1.56 for specific types of events. The risk-adjusted result for readmission within 1 month associated with at least one safety event was 1.17 ($P < 0.01$). However, the models for specific safety events gave a significantly high risk of readmission within 1 month for only 2 of the more common types of safety events.

Conclusions: Hospital readmissions are one way that safety events can have costly consequences. More attention is warranted to assess the full extra cost of safety events, the factors influencing the rate of safety events, and strategies for health plans to improve incentives for safety.

Key Words: patient safety, hospital readmissions

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MOTIVATION AND PURPOSE

The Institute of Medicine (IOM) defined patient safety as freedom from accidental injury due to medical care.[1] There is no comprehensive approach to measuring patient safety in the hospital, but measures for a number of specific indicators of safety-promoting practices (eg, appropriate timing of antibiotics for surgery patients), or types of safety events (eg, iatrogenic pneumothorax) for hospitalized patients have been developed based on literature reviews and clinical panel reviews for the Center for Medicare and Medicaid Services or the Agency for Healthcare Research and Quality (AHRQ). AHRQ uses Patient Safety Indicators (PSIs) together with other measures to track national health care quality.[2] Descriptions, software, and clinical panel reviews for these PSIs are obtainable from the AHRQ website. For each indicator, an at-risk population of patients is defined, based on diagnoses and procedures, with some types of patients or situations excluded. Patient safety events, measured by the AHRQ PSIs, have been associated with excess deaths and excess charges per admission.[3]

Any one type of PSI is relatively infrequent (generally less than 1% of patients are affected). For example, the rate for "postoperative sepsis" was in the middle of the range at 0.45% of those patients at risk for this PSI. However, the rate of occurrence of at least one safety event in a patient admitted for surgery is considerably more than that (2.63% for the 9 types of safety event in this study). Research on the effect of PSIs has been motivated by a widespread belief that many, even most, such events are preventable. Hospitals and physicians may not have strong financial incentive to prevent safety events. There are direct costs of improving safety, such as costs of staffing and training. In addition, other obstacles could be the organizational structure, historical inertia in governance of the hospital, and environmental constraints.[4,5] Recently, Mello et al argued that most of the extra social costs of safety events in a hospital are not borne by the hospital. Costs can be covered by additional charges to the same patient and other patients, insurance coverage for malpractice awards is pooled across all other covered providers, and some costs to patients are never compensated.[6] One other study estimated substantial excess payments by the Medicare program for hospital stays with any of 5 selected adverse events, but concluded that a majority of the excess cost was borne by the hospital itself.[7] That study did not consider either the costs to patients and families of premature mortality, or the possibility of recovery of treatment cost by charging more to other payers.

Excess costs may not end with a single hospital stay. Ashton et al conducted a metaanalysis of studies showing an

effect of better quality of care in the hospital on reduced readmission rates.[8] The review covered studies that relied on patient charts and peer review. Those studies generally included relatively small patient samples and fewer hospitals than now available with administrative data and standardized algorithms. A more recent study by Smith et al used administrative data from the Medicare program to study rehospitalization and survival for elderly stroke patients.[9] Using private insurance claims data for a limited set of surgical hospitalizations, Encinosa and Hellinger found safety events to be associated with higher payments in the 3 months after hospitalization—the higher payments included ambulatory care and hospital readmissions.[10]

The purpose of this article is to provide tests of the impacts of safety events associated with an initial admission for surgery on the likelihood of death or readmission. We use a large, multistate, multidiagnosis, and all-payer database. We employ a methodology to address deaths and readmissions simultaneously, since deaths reduce the possibility of readmission. The study controls for severity of illness, comorbid chronic conditions, payer group, and other variables pertaining to the patient. In addition, we allow for correlation of unmeasured determinants of patient outcome associated with the hospital where the initial surgery took place. The primary null hypothesis of the study (H1) is that, controlling for deaths, the likelihood of readmission would not be affected by occurrence of a safety event. There is an alternative hypothesis. The literature reviewed by Ashton et al and the study of privately insured patients by Encinosa and Hellinger suggest that patients discharged alive with a safety event will have a higher rate of readmission than patients with no safety event.[8,10]

PAYER DIFFERENCES IN READMISSIONS

Although patient characteristics and safety events are the main testable determinants of death or readmission in this study, 1 nonclinical influence will be tested—specifically, the patient's payer type. The null hypothesis (H2) is that payer type has no independent effect on the rate of readmissions. However, there are reasons to suspect a net positive association of Medicare with the rate of readmissions, compared with the privately insured patients. Readmissions are an undesirable cost to any payer as well as to patients—especially patients paying a relatively high share of the cost. Private insurers can potentially select hospitals and physicians, or reward them, for keeping readmissions low. A number of strategies, specifically to reduce readmissions, can be used in private health plans. These include sharing the savings with hospitals and physicians and care coordination programs for the chronically ill when readmission rates are kept below benchmark rates.[11]

The Medicare fee-for-service program sets a payment that, for most hospitals, depends essentially on the national average cost of treating a patient in a particular diagnostic group, regardless of the actual costs of treating a specific patient. Compared with private insurers, the Medicare payment is relatively "flat" and Medicare is constrained to include essentially all licensed hospitals and physicians. These features make the Medicare fee-for-service program not only less at-risk for the excess cost of safety events during the initial admission, but also less able to influence readmissions through incremental rewards or selective contracting. (There have been some actions following the Deficit Reduction Act of 2005 to reduce Medicare payment in the event of some types of safety events (eg, hospital-acquired infections). In addition, public reporting of quality differences between hospitals by the CMS, including risk-adjusted mortality, is expanding in scope).

Medicaid beneficiaries face no out-of-pocket cost of readmissions, and the patient's access to outpatient care in physician offices is often less than for privately insured patients. This situation could increase readmissions. However, many states use capitation contracts for Medicaid so that contracting health plans have an incentive to discourage use of specialists and hospital admissions. For self-pay patients, the out-of pocket cost may discourage readmissions, but the out-of-pocket cost may also discourage adequate use of drugs and other outpatient services in the management of chronic illness.

DATA AND METHODS

The starting database for the study consists of adults hospitalized in 7 geographically dispersed states (California, Florida, Missouri, New York, Tennessee, Utah, and Virginia) for surgical procedures during January through September 2004. The data were assembled from the State Inpatient Databases of the Healthcare Cost and Utilization Project maintained by AHRQ. More specifically, the initial ("index") admission DRG was for a surgical procedure. The flow of index admissions and rehospitalizations selected for the study is as follows.

1. Retain a person in the study if: age 18 or older, not transferred from another hospital, initial Major Diagnostic Category (MDC) not 14 (pregnancy or birth-related), at risk for at least 1 of the 9 types of safety events.
2. Identify the first rehospitalization within 3 months and retain as a readmission if: not transferred from another hospital, MDC not 14, the principal diagnosis is in a Clinical Classification System (CCS) category outside the range 225–236 (this is the range for trauma-related injury or poisoning).
3. Determine whether the first readmission is within 1 month. Note that each person can have at most one readmission in the study. The excluded CCS categories for readmissions contain principal diagnoses of trauma-related injuries or poisoning, but late effects of prior events are retained (ICD9 codes 905xx–909xx). The full CCS classification is available at http://www.hcup.us.ahrq.gov/toossoftware/ccs/AppendixASingleDX.txt.

About 1.5 million persons from the 7 states met the criteria of surgical DRG at risk for any of the 9 safety events. (A small percentage of discharges indicated that the patient was admitted by transfer from a different hospital. Such cases were excluded as either index admissions or readmissions). An encrypted patient identifier is supplied by the data source

agencies. This identifier is used along with age and gender to identify eligible readmissions for a single person.[12] A 3-month period for readmissions is arbitrary. Brennan et al reported that between 50% and 70% of patients with adverse events recovered within 90 days; however, that was not specifically a study of hospital readmissions.[13] The analysis here was done with a 3-month time limit for readmissions, then repeated for a 1-month time limit. Roughly 2 of 3 of readmissions within 3 months occur within the first month.

Patient Safety Indicators

A research team at the medical centers of the University of California and Stanford University developed the AHRQ PSIs through a 5-step process.[14,15] The PSIs, which have been continually improved over the last several years, are specifically designed for screening administrative data for incidents of concern related to patient safety and include 20 indicators with support from the literature and clinical panels. Many of these PSIs were shown to be associated with substantial excess charges and excess mortality.[3] An important aspect of each PSI measure is that the "at-risk" population of relevant patients excludes cases where the adverse event is inherently likely, regardless of the performance of physicians and hospital staff. More details on the development and validation of these indicators, together with the latest downloadable software, are available from the AHRQ website.[16] For this study, we selected 9 postoperative PSIs. These are iatrogenic pneumothorax, selected infections because of medical care, postoperative hemorrhage or hematoma, postoperative physiologic and metabolic derangements, postoperative respiratory failure, postoperative pulmonary embolism or deep vein thrombosis, postoperative sepsis, postoperative wound dehiscence in abdominopelvic surgical patients, and accidental puncture or laceration of organs. Two PSIs relevant to surgical adult patients were dropped because of concern about their being frequently present on admission: decubitis ulcer and postoperative hip fracture.[17] The PSI for foreign objects left in body was dropped because of rarity. The PSI for complications because of anesthesia was excluded because of concerns about coding consistency. Two PSIs were dropped because the measurement is focused on patients who died.

The at-risk populations and rates of events for our 9 selected PSIs are shown in Table 1. The occurrence rates for particular PSIs in their own at-risk populations ranged from 0.07% to 0.9%. Individually, these are not common events. However, the likelihood of at least one event among patients at risk for at least one event is a much larger 2.6%. Rarely does a patient have more than one of these safety events (less than 0.2%). Such patients appear only in the description and analysis of patients at risk for at least one safety event. These patients are in the last row of the table.

TABLE 1. Prevalence of Safety Events

Patient Safety Event	Patients at Risk	Rate of Safety Event
Iatrogenic pneumothorax	1,280,518	0.09%
Selected infections due to medical care	871,827	0.24%
Postoperative hemorrhage or hematoma	1,369,162	0.16%
Postoperative physiologic and metabolic derangements	779,609	0.07%
Postoperative respiratory failure	656,730	0.72%
Postoperative pulmonary embolism or deep vein thrombosis	1,365,723	0.74%
Postoperative sepsis	174,294	0.45%
Postoperative wound dehiscence after abdominopelvic surgery	300,974	0.12%
Accidental puncture or laceration	1,409,547	0.90%
Patients at risk for at least 1 type of safety event	1,412,849	2.63%
At least 1 of 9 postoperative safety events (includes patients with multiple safety events)		

Severity and Risk of Mortality

Severity of illness was measured by the proportion of cases in any APR-DRG group with severity levels 3 or 4. The APR-DRG classification and Severity of Illness levels take into account principal diagnosis, unrelated secondary diagnoses, procedures, and age.[18] Nevertheless, we entered age ranges in the multivariate models to control for any remaining effect on readmissions or deaths because of unmeasured severity related to age. Another indicator provided by the APR-DRG developers is a Risk of Mortality scale, based on principal and secondary diagnoses, age, and other factors. A value of 2 indicates "moderate" risk of mortality, whereas values of 3 or 4 indicate major risk of mortality (about 10% of admissions). The use of the Risk of Mortality and Severity of Illness categories in our study is a conservative strategy that may capture some complications of treatment, leaving less to be explained by a PSI event separately.

In addition to the severity measures, we also controlled for the presence of 18 selected secondary chronic conditions. These are a subset of the 30 comorbid conditions shown to predict inpatient charges and mortality.[19] Some of these 30 conditions were combined and others were dropped due to rarity in the sample. Downloadable software for these comorbidities is available at the AHRQ website. Chronic conditions are particularly likely to influence the likelihood of readmission within 3 months. Examples are congestive heart failure, chronic lung diseases, depression and other mental/psychiatric disorders, diabetes, hypertension, liver disease, renal failure, and metastatic cancers. Finally, we controlled for common procedures in the following way: Starting with the 25 surgery DRGs with at least 1% of adult surgery cases, we dropped 11 of these because the DRG was too rare in the at-risk population. That is due partly to the exclusion of many emergency procedures in the definition of the at-risk popula-

TABLE 2. Outcomes in Relation to Safety Event*

Outcome	No Safety Event (N = 1,375,691)	After Safety Event† (N = 37,158)
Died before discharge (%)	1.30%	9.17%
Readmitted within 3 mo (%)	16.54%	24.86%
Readmitted within 1 mo (%)	10.91%	15.75%
Discharged alive and not readmitted within 3 mo (%)	82.16%	65.97%

*For patients at risk for at least 1 type of safety event.
†At least 1 of the 9 safety events present.

tions. The list of DRGs controlled is 75, 107, 109, 110, 148, 209, 210, 288, 358, 359, 478, 493, 520, and 527.

Analytic Strategy

We applied a multinomial logistic model to the likelihood of different outcomes of a discharge.[20] The 3 mutually exclusive outcomes, j = 0,1,2, are 0 for discharged home with no admission, 1 for died, and 2 for readmitted. The independent variables X_k, for k = 1,. . .,K (eg, occurrence of safety event, severity of illness, particular chronic comorbidities, payer group) are allowed to have different effects on each type of outcome. The key mathematical assumption is that the probability of outcome j,

TABLE 3. Means for Independent Variables Patients at Risk for At Least 1 of 9 Safety Events

	Outcome		
	Died Before Discharge (N = 21,356)	Readmitted Within 3 Months (N = 236,251)	Neither (N = 1,155,242)
Multiple safety events	0.0278	0.0024	0.0010
Age 18–44	0.0796	0.1378	0.2552
Age 45–64	0.2278	0.3245	0.3679
Age 65–74	0.2151	0.2302	0.1872
Age 75+	0.4775	0.3075	0.1897
Female	0.4578	0.5106	0.5617
Medicare	0.6786	0.5628	0.3810
Medicaid	0.0874	0.0834	0.0726
Self-pay	0.0341	0.0251	0.0399
Privately insured	0.1999	0.3287	0.5065
Severity levels (APR-DRG software)			
Risk of mortality, level 1	0.0257	0.5064	0.7609
Risk of mortality, level 2	0.0912	0.3190	0.1754
Risk of mortality, level 3 or 4	0.8831	0.1746	0.0637
Severity of illness, level 1 or 2	0.0843	0.6959	0.8660
Severity of illness, level 3 or 4	0.9157	0.3041	0.1340
Comorbidities, unrelated to principal DX (derivation in text)			
Anemia	0.0278	0.1740	0.0137
Congestive heart failure	0.2228	0.0681	0.0249
Chronic lung disorder	0.2425	0.1720	0.1149
Depression and other mental disorders	0.0963	0.0996	0.0773
Diabetes and complications	0.1917	0.2315	0.1452
Hypertension	0.4172	0.5090	0.4004
Hypothyroid conditions	0.0588	0.0802	0.0698
Liver conditions	0.0435	0.0191	0.0128
Fluid and electrolyte disorders	0.4234	0.1358	0.0674
Metastatic cancer	0.1008	0.0527	0.0217
Neurologic disorders	0.0804	0.0431	0.0247
Obesity	0.0336	0.0628	0.0595
Paralysis	0.0398	0.0201	0.0092
Perivascular diseases	0.0979	0.0835	0.0366
Renal failure	0.1143	0.0527	0.0142
Tumor (except metastatic cancer)	0.0289	0.0232	0.0096
Cardiac valve disorder	0.0644	0.0391	0.0272
Weight loss	0.1051	0.0233	0.0081

$$P\{j\} = exp[\Sigma'_k(B_{jk} \times X_k)]/(1 + \Sigma'_j\, exp[\Sigma'_k(B_{jk} \times X_k)])$$

where *exp* is the exponentiation function with base *e*, B_{jk} is the coefficient of X_k for outcome type j, and $'\Sigma$ is the sum of the subsequent expression over all values of j or k as indicated. Note that the denominator is the same for all j. Because the admission types are mutually exclusive, we can only estimate probabilities for death or readmission relative to probability of discharge home with no readmission. Specifically, the relative probability for death is

$$P\{j = 1\}/P\{j = 0\} = exp[\Sigma'_k(B_{1k} \times X_k)]/ exp\,[\Sigma'_k(B_{0k} \times X_k)]$$

Suppose that X_k were the occurrence of a safety event, a dichotomous variable. In the occurrence of a safety event, holding constant all other variables, the relative probability (relative risk ratio or RRR) is $exp[B_{1k}\text{-}B_{0k}]$. This is the analogue to the odds ratio from the logistic model with 2 outcomes. Neither of the 2 parameters can be estimated separately. Because all independent variables in our model are dichotomous, all the results to be presented will be relative risk ratios.

The model is fit by maximum likelihood methods, with inclusion of the assumption for correlated errors for patients with the same hospital of the index admission ("clustering"). Without this allowance for correlated errors, the precision of estimation with a large sample of cases would be overestimated.

FINDINGS

Tables 2 and 3 provide descriptive information. Table 2 shows large differences in outcome, depending on whether a safety event occurred or not. The rate of death increased by a multiple of 7 if a safety event occurred. The rate of readmission within 3 months increased by 50%, whereas the rate of readmission within 1 month increased by 44%, after a safety event. Table 3 shows the mean rate for each of the other independent variables within each outcome in the model for patients at risk for at least one safety event. Looking across the rows in this table, one finds an indication of the univariate association of particular variables with outcome. For example, Medicare coverage was more frequent among patients who died, somewhat less frequent among patients with readmissions, and even less common among patients with neither outcome.

Table 4 provides the key results of the study pertaining to primary hypothesis H1. Nine separate models were fit, using the patients at risk for each PSI. The relative risk ratio for death was significantly greater than 1.0 in 8 of the 9 models. The highest RRR for death occurred in association with postoperative respiratory failure and in association with postoperative sepsis. The RRR for readmission within 3 months was significantly different from 1.0 in each of the 9 models. The RRR for readmission within 1 month was only significantly different from 1.0 in 2 of the models for individual safety events. These were for "pulmonary embolism and deep vein thrombosis" and "accidental puncture or laceration." These were the 2 safety events with the highest

TABLE 4. Results of Multinomial Logistic Regressions*

		Relative Risk Ratio of Outcomes Due to Adverse Event†		
	Patients at Risk	Death Before Discharge‡	Readmission Within 3 Months	Readmission Within 1 Month
Iatrogenic pneumothorax	1,280,518	2.47§	1.20§	1.02
Selected infections due to medical care	871,827	1.23¶	1.29§	1.00
Postoperative hemorrhage or hematoma	1,369,162	1.03	1.18§	1.10
Postoperative physiologic and metabolic derangements	779,609	3.73§	1.30¶	1.09
Postoperative respiratory failure	656,730	13.23§	1.14§	1.03
Postoperative pulmonary embolism or deep vein thrombosis	1,365,723	1.35§	1.28§	1.25§
Postoperative sepsis	174,294	4.70§	1.26§	0.99
Postoperative wound dehiscence in abdominopelvic surgical patients	300,974	1.57¶	1.56§	1.24
Accidental puncture or laceration	1,409,547	1.52§	1.16§	1.25§
Patients at risk for at least 1 type of safety event				
At least 1 of 9 postoperative safety events	1,412,849	1.65§	1.20§	1.17§

*Results control for age, gender, severity levels in APR-DRG coding system, payer group, presence of specific comorbid conditions, and specific surgical DRGs. There were approximately 1080 hospitals represented.

†Relative risk ratio = (likelihood of outcome)/(likelihood of being discharged alive with no readmission), for patients with safety event. If no safety event, the relative risk ratio is 1.0.

‡These are the results for the multinomial model corresponding to tests for readmissions within 3 months. The results for the model testing for readmission within 1 month are slightly different–for example, see Table 5 where the RRR of death falls from 1.65 to 1.60.

§$P < 0.01$ for difference of relative risk from 1.0.

¶$P < 0.05$.

TABLE 5. Detailed Regression Results, Patients at Risk of Any of 9 Safety Events*

	Model A				Model B			
	Death Before Discharge		Readmission Within 3 Months		Death Before Discharge		Readmission Within 1 Month	
	Relative Risk Ratio	z	Relative Risk Ratio	z	Relative Risk Ratio	z	Relative Risk Ratio	z
Occurrence of a safety event	1.654	17.16†	1.200	12.07†	1.602	16.46†	1.166	8.46†
Multiple safety events	1.815	9.53†	0.958	−0.85	1.762	9.33†	0.809	−3.4†
Age 45–64	1.232	6.20†	1.233	20.09†	1.200	5.44†	1.187	14.61†
Age 65–74	1.285	6.10†	1.086	4.76†	1.283	6.07†	1.083	3.97†
Age 75+	1.782	14.16†	1.215	10.45†	1.758	13.88†	1.229	9.58†
Female	0.993	−0.46	0.997	−0.49	0.993	−0.42	0.996	−0.54
Medicare	1.159	4.83†	1.446	29.50†	1.099	3.07†	1.388	20.53†
Medicaid	1.539	10.79†	1.521	27.16†	1.450	9.37†	1.467	20.00†
Self-pay	1.597	7.83†	0.924	−3.05†	1.614	8.05†	0.949	−1.71
Severity levels from APR-DRG classification system‡								
Risk of mortality (level 2)	6.058	31.10†	1.565	49.51†	6.070	30.99†	1.505	35.52†
Risk of mortality (level 3 or 4)	60.969	70.80†	1.779	43.10†	59.320	70.34†	1.646	31.06†
Severity of illness (level 3 or 4)	3.641	38.80†	1.403	33.58†	3.484	37.53†	1.348	24.30†
Risk adjustment controls for 18 unrelated chronic comorbidity groups (see Table 3)								
Controls for 14 DRG categories of initial admission								
No. patients = 1,403,714; treated in 1088 hospitals								
Pseudo R^2 = 0.12 (both Model A and Model B)								

*Standard errors corrected for correlation of unmeasured errors for patients in the same hospital.
†Relative risk ratio significantly different from 1.0 at $P < 0.01$.
‡The APR-DRG classification is a product of 3M, Inc. Basic description of the algorithms for severity levels is given in Averill (2000), taking into account unrelated secondary diagnoses, age and procedure.

event rates and with relative large patient populations at risk. The final row of the table shows the models fit to persons at risk for any safety event. This model was also fit twice for different time limits. In either case, the RRR for death among patients with a safety event was about 1.6, whereas the RRR for readmission was approximately 1.2.

Table 5 gives more detailed results for the multinomial model for occurrence of death or readmission in patients at risk for at least one safety event. Model A is for readmission within 3 months as the readmission definition, and model B is for readmission within 1 month. Specific effects for the comorbid conditions and types of surgery were not reported in the interest of space and to focus on the key findings. This table of results is qualitatively illustrative of the results of each of the statistical models, except for the effects of multiple events which are relevant only in this model. The occurrence of multiple events, although rare, shows a significant RRR for death, but not for readmission. Severity levels in the APR-DRG classification system have low standard errors for their effects and show powerful effects on both outcomes. To the degree that APR-DRG severity measures already adjust for adverse events of interest, they tend to impart a conservative downward bias to the independent association of safety events with outcomes.

The patient's payer group is associated with risk of death or readmission, independently of adverse events and other diagnoses and severity factors. The results for Medicare are in the direction of the alternative to the null hypothesis H2. Compared with privately insured patients, Medicare and Medicaid patients contributed higher RRR for both death and readmission, after controlling for age, gender, and all the clinical factors. Self-pay patients contributed to a higher RRR of death, but a lower risk of readmission within 3 months. The reduced rate of readmission within 1 month was not significant for self-pay patients.

DISCUSSION

Rates of 9 safety events in large, at-risk populations of surgical patients are each less than 1% and sometimes much lower. Also, for some of these particular events, the proportion of patients defined to be at risk was less than half of surgical patients and in 2 cases less than a fifth. Therefore, it requires a large population of patients to ensure sufficient statistical power to distinguish the impact of safety events and covarying factors on outcomes of death or readmission. Using large administrative databases to control for the effects of severity of illness, comorbid conditions, and type of surgery, the models presented in this article illustrate a feasible way to test simultaneously for death and readmission as possible outcomes of safety events. For the composite safety event model (any of the safety events among patients at risk for at least one), the results are not consistent with the null hypothesis of no effect on readmissions (H1). The independent contribution of safety events to mortality is often quite large (RRR = 1.65 for the composite indicator in the

model for outcomes as of 3 months, and 1.60 in the model for outcomes as of 1 month). The contribution of safety events to the risk of readmission within 3 months is consistently significant (RRR = 1.2 in the model for any of 9 safety events). However, the relative risk of readmission within 1 month is significantly affected by a safety event for only 2 of the safety events and for the composite measure of any safety event.

Given the high cost of any hospital stay, extra readmissions are a substantial cost to a health plan and to patients. The extra costs due to readmission after safety events should be considered by health plans as part of the potential savings from changing incentives for hospitals and physician groups to achieve fewer safety events, or from selecting service providers with better safety performance. In this study, it is not possible to estimate the net marginal cost of safety events because we are not tracking all the cost of care after an initial discharge. It is possible that patients who were not readmitted used considerable resources to manage their health conditions outside the hospital.

Although there is not much comparable literature using large scale administrative databases on effects of safety events on readmissions, there is some evidence about deaths associated with safety events published by Zhan and Miller.[3] Those authors, using 16 PSIs, estimated a national count of 32,600 "excess" deaths based on the AHRQ 2000 Nationwide Inpatient Sample, which consists of all cases in 994 hospitals. We cannot make a comparable estimate in the current study. We were more selective in choosing PSI measures, we use only adult surgical patients, only the initial surgical admission is examined for safety events, and we do not aggregate across conditions. Interestingly, the 3 highest relative risks of death in Table 4 are the same as the 3 PSIs associated with the highest percentage of excess deaths in the Zhan and Miller study[3]. The following calculation may be of some interest for others who might take a similar approach to the one used here for persons at risk for any of a number of safety events. The overall death rate for persons at risk for one, the 9 safety events here was 1.51%. This is a weighted average of the risk-adjusted death rate for those with no safety events (1.485%) and the risk-adjusted rate for patients with a safety event (2.45%). The occurrence of at least one safety event was associated with almost a 1 percentage point increase in the death rate for patients with a safety event. (Let X be the risk-adjusted rate with no safety event. It is solved from the following equation: $0.0151 = 0.9737 \times X + 0\ 0263 \times 1.65 \times X$. This is limited to the model for occurrence of any safety event and not an aggregate across safety events).

The results of multivariate tests are consistent with a substantial effect of Medicare on readmissions (rejecting null hypothesis H2). Also, Medicaid is associated with a higher rate of readmissions, whereas self-pay is associated with a lower rate (the latter not significant for readmissions within 1 month). After considering the financial incentives facing hospitals and physicians, we are not surprised to find a higher rate of readmissions for Medicare patients compared with privately insured patients. The public programs do not yet have the same flexibility as private insurers to select and reward local hospitals and physicians depending on performance. A cautionary note is in order: even though age ranges, severity measures, and comorbid conditions are included in the models, it is still possible that some of the increase in death or readmission attributed to Medicare and Medicaid enrollment may be due to unmeasured severity of illness.

It is clear that the Medicare program intends to penalize hospitals for safety events by reducing payments from what they would otherwise have been. The Deficit Reduction Act of 2005 marked a beginning in this activity by calling for reducing payments for cases with "hospital acquired infections." Such payment reductions began in fiscal 2008 for a set of hospital-acquired infections, and are facilitated by better hospital reporting on whether each diagnosis was present on admission. A recent press release shows how much farther the Medicare program is aiming to go with penalties for safety events and other measures of "never events."[21] A number of the AHRQ safety events, including some composite indicators that will appear in future issues of the National Healthcare Quality Report, have been proposed in broader federal programs for value-based purchasing. Fourteen chartered value exchanges were selected in 2008 to receive federal assistance in compiling and sharing information on cost and quality of care in their areas. Press releases from Cigna and the Leapfrog Group in 2008, available on their respective websites, indicate that private insurers and employer coalitions are also taking steps to reduce payments for never events, a term created in 2006 by the National Quality Forum to cover a set of rare adverse events that partially overlap Medicare indicators for reporting and eventual value-based purchasing.

The analysis here has data limitations. First, a person may have died outside a hospital after the index hospitalization and, hence, the likelihood of readmission was reduced. One might expect that this would happen more often for persons with the greatest severity of illness or persons who suffered safety events. Second, a common limitation in this kind of study is that administrative data include as adverse events some secondary diagnoses that were present on admission. Every PSI has some exposure to this problem, although the most problematic indicators were excluded from the study. When administrative data are better reinforced with additional clinical information, hospital safety event measures can be employed with greater accuracy. Finally, the study does not attempt to restrict rehospitalizations to only those who are likely to be associated with a complication of surgery or safety event. Instead, 2 large but clearly irrelevant classes of subsequent hospitalization were dropped (ie, trauma and pregnancy-related) and measures for severity and unrelated chronic illness were used to statistically control for determinants other than safety events. Other methods may be more useful to clinicians concerned with quality improvement for particular types of patients and treatments in the hospital.

One direction to build on the methods and findings of the current study is to investigate the variation across hospitals in safety events and the possible determinants of that

variation. Competition among hospitals and physicians in a local area, and competition among health plans might each affect safety event rates. It would be important to address selective referral behavior that might result in the most difficult cases arriving at the safest hospitals but making those hospitals to appear less safe than others.

Despite new payment strategies in the Medicare program, it will undoubtedly take considerable time to meet the Institute of Medicine call for a 50% reduction in patient safety events.[1] It takes time to demonstrate programs involving training and staff recruitment, altered operational protocols, environment controls and so forth, that have a promise of reducing postoperative complications. As these programs become better demonstrated, health plans could use positive rewards for such activities as well as penalties for safety events. Some safety events depend not only on hospital staff and environment, but also physician performance and perhaps selection of patients to better balance risk and benefit. Although the determinants of safety events may be complex, a blend of training, recruitment, public reporting, financial rewards, and penalty strategies can be used to improve safety. Measures of safety events and evidence of their association with consequences such as death, extra cost of hospital stays, and extra readmissions are improving. It is hoped that the improved measures and evidence will be useful to health plans, clinicians, and managers when they seek to improve safety and reduce unnecessary costs of safety events.

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