RESEARCH ARTICLE

Estimating the hospital costs of inpatient harms

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Funding information

Center for Medicare and Medicaid Innovation, Grant/Award Number: GS-10F-0166R

Objective: To estimate the additional hospital costs associated with inpatient medical harms occurring during an index inpatient admission and costs from subsequent readmissions within 90 days.

Data Source: 2009 to 2011 Healthcare Cost and Utilization Project's State Inpatient Databases from 12 states.

Study Design: We compare hospital costs incurred by patients experiencing a specific harm during their hospital stay to the costs incurred by similar patients who did not experience that harm.

Data Extraction: We extracted records for adult patients admitted for a reason other than rehabilitation or mental health, were at risk of a harm, and were admitted for less than a year.

Principal Findings: The costliest inpatient harms, such as surgical site infections and severe pressure ulcers, are associated with approximately \$30 000 in additional index stay costs per harm. Less costly harms, such as catheter- or hospital-associated urinary tract infections and venous thromboembolism, can add \$6000 to \$13 000. Birth and obstetric traumas add as little as \$100.

Conclusions: Our analysis represents rigorous estimates of the hospital costs of a variety of inpatient harms; these should be of interest to health care administrators and policy makers to identify areas for cost savings to the health care system.

KEYWORDS

acute inpatient care, health care costs, inpatient harm, quality of care, readmissions

1 | INTRODUCTION

Hospital inpatient medical harms are defined as injuries to patients that occur while hospitalized. The Agency for Healthcare Research and Quality (AHRQ) estimates that there were 98 harms (which they measure using specific inpatient harm diagnoses known as hospital-acquired conditions, or HACs) per 1000 discharges in 2014.¹ These harms not only impact the health and wellbeing of patients and families but also add a significant financial burden to the U.S. health care system. Examples of inpatient harms include surgical site infections (SSI), falls that result in severe injuries, and severe (stage III and above) pressure ulcers that were not present when the patient was admitted. Past studies have addressed the economic and financial consequences of several hospital-associated harms; for example, according to a literature review of

empirical research on the additional cost of HACs,² estimates of the additional cost of SSI range between \$12 000 and \$42 000, and the cost of pressure ulcers from approximately \$9000 to \$21 000. Most of the previous studies have not, however, accounted for or taken advantage of two important changes in hospital Medicare payment policy. First, beginning on October 1, 2007, Medicare required hospitals to indicate whether diagnoses on their claims were "present on admission" (POA), thus enhancing researchers' ability to identify the occurrence of inpatient harms in claims data. Second, on October 1, 2008, Medicare stopped providing reimbursement for services provided to treat a specified list of HACs that were not POA. In addition, previous studies have examined the additional costs of inpatient harms during the initial hospitalization only and have not considered additional costs occurring after discharge from the initial hospitalization.

This study estimates additional hospital costs associated with specific inpatient harms. We estimated costs during the index admission that would not have occurred if the harm had not taken place, as well as the change in the readmission rate within 90 days and the costs associated with additional readmissions. We used 2009-2011 data from 12 states from AHRQ's Healthcare Cost and Utilization Project's State Inpatient Databases (HCUP SID). We detected medical harms using the Patient Safety Indicators (PSIs) developed by AHRQ as well as the Centers for Medicare & Medicaid Services (CMS) HAC indicators.

Our study contributes to the existing literature on the cost of hospital-acquired harms in several important ways. One important development is that our analysis incorporated POA indicator data signifying whether the diagnosis was POA, which past studies have shown is critical for identifying whether the medical condition was acquired during the hospital stay and therefore considered an inpatient harm.^{3,4} Much of the past literature did not have access to POA data and is likely to have counted too many discharges as having inpatient harms. For example, POA data are critical to distinguish between severe pressure ulcers that developed during the hospital stay (which should be considered an inpatient harm) from severe pressure ulcers the patient already had before being admitted (which should not be considered an inpatient harm).

Another contribution of our paper is that we used a large administrative dataset (the HCUP SID) that includes all hospitals in a dozen states and claims data from all payers. In contrast, much of the existing work used data from only a few states^{5,6} or focused on a narrower subset of harms.⁷⁻⁹ The few studies that estimated the cost of a wide variety of inpatient harms for a nationwide sample used either commercial insurance data with limited or no data on POA indicators¹⁰ or data from a single payer such as Medicare¹¹ or a health care system serving a specific population.¹² Nationwide estimates focusing on a single payer or specific populations are limited in their generalizability.

Our analysis employed a rigorous matching procedure to construct a comparison group for calculating our counterfactual measure of what hospital costs would have been had the patients not experienced the harm. Across all the harms studied, we were able to match 98%-100% of discharges with inpatient harms to comparison patients without harms in the same hospital that shared the same year and base diagnosis-related group code. Successfully constructing a well-balanced comparison group alleviates many concerns about our cost estimates being due to differences in characteristics between the treatment and comparison groups instead of being due to the occurrence of the inpatient harm.

In an existing study most similar to ours,¹³ researchers used the HCUP data to estimate the cost of a large variety of inpatient harms nationwide; however, their identification of hospital-acquired harms was less reliable than ours because they used older data (from 2000) that did not contain POA information and used an older version of the AHRQ PSI software, both of which produce a high rate of false positives as discussed above. Their matching procedure also had a much lower match rate than

our matching procedure, suggesting that our study includes a wider variety of patients with inpatient harms and a more reliable comparison group. Furthermore, their study used the HCUP National Inpatient Sample, which is unable to track readmissions to estimate the cost of subsequent hospitalizations due to medical harms in addition to the cost of the index stay.

In summary, our paper makes a valuable contribution to the existing literature by improving the identification of medical harms, providing rigorous estimates on a variety of harms for a large sample of patients that are covered by all different types of payers, and estimating costs incurred during the index hospitalization when the harm occurred plus subsequent hospitalizations following the inpatient harm.

2 | DATA AND METHODS

Using the HCUP SID, we compared the cost of hospital stays for patients who experienced inpatient harms to the costs of similar stays when no inpatient harm occurred. We also compared the readmission rates for stays with and without these harms.

2.1 | Data

We conducted all analyses using the HCUP SID. The SID is composed of inpatient discharge abstracts that, in total, encompass almost 90% of all U.S. hospital discharges. It contains clinical and nonclinical information on all patients, regardless of payer. Forty-eight organizations submit annual data to HCUP on state-specific timelines. Although most of the variables are uniform across all data sets, there are also state-specific data elements, such as hospital identifiers and POA variables. We used data from 2009 to 2011 for the 12 states that have the state-specific data required for our analysis. See Table S1 for the states and years that were included; we purchased the most recent years of data available for each state at the time when the analyses began in 2012. Using a subsample of states limits the generalizability of our results; however, the population of states used included at least one state from 8 of the 10 U.S. Department of Health and Human Services (HHS) regions, and the sample is large enough to capture an extensive number and variety of inpatient harms across the country. We also used the American Hospital Association's (AHA) 2010 hospital survey to obtain hospital characteristics.

We limited the sample to patients more than 18 years old (except for the measures pertaining to birth and obstetrical care) who were admitted to an acute care hospital for a reason other than rehabilitation or mental health issues, had a length of stay between 0 and 365 days, and were at risk of the specific harm being studied.

2.2 | Inpatient harm indicators

We used AHRQ's PSIs and CMS's HACs as the main measures of inpatient harms. Table 1 includes a list of harms of interest

for this study and specific measures used for each. We used the first nine diagnosis codes, the first six procedure codes, and all available E-codes to produce the measures. We accounted for inconsistent reporting of POA indicators in SID data by dropping patients whose POA indicator was missing or invalid for a relevant diagnosis code needed to develop the medical harm indicator. Missing or invalid POA indicators for the primary diagnosis occurred for <1% of the raw input data [Agency for Healthcare Research and Quality (AHRQ) in Rockville, MD, USA].

2.3 | Cost measures

This study focuses on two measures of hospital costs: (a) the cost of the index stay; and (b) the cost of the index stay plus additional stays occurring in a 90-day follow-up period. The HCUP SID data provide hospital charges that generally do not include professional fees or noncovered charges; emergency department charges incurred before admission may be included. Hospital charges are the hospital's list price for its services but are often unrelated to the actual cost of providing care; as a result, we created the cost variables by multiplying the charges by hospital-specific cost-to-charge ratios, which we obtained from HCUP. When hospital-specific ratios were not available, we used group-specific cost-to-charge ratios instead.

Only seven of the 12 states included data elements that made it possible to track readmissions (see Table S1). The HCUP data have a verification process in which readmissions must have the same person number, date of birth, and sex to be considered the same patient over time; the percentage of cases aged 18-64 that were verified for the states in our sample was above 94% for all but two states: Iowa had 69% of verified cases and California had 88%.¹⁴ We created the 90-day cost variable for discharges from these seven states by summing the costs for the index stay and those of any subsequent acute hospital stays when the admission date of the readmission occurred within 90 days of the index stay's discharge date. We included any readmission following the index stay in the 90-day cost measure, regardless of whether the readmission was directly attributed to the inpatient harm.

We excluded hospital stays from the analyses if charges were missing or less than \$100 and bundled stays for patients who transferred among facilities into one stay. If cost information for any piece of the transfer process was missing, we did not include the bundled stay in the analyses. We did not include stays in the 90-day cost analysis if (a) the index stay costs were missing or zero; (b) any subsequent readmissions within the 90-day follow-up period had charges that were zero, partially missing (in the cases of transfers), or fully missing; or (c) the 90-day cost value was less than \$100. Table S2 shows the sample sizes after each exclusion criterion.

Inpatient harm	Description	HAC or PSI
CAUTI	Catheter-associated urinary tract infection	HAC CAUTI
HAUTI	Hospital-acquired urinary tract infection	— ^a
CRBSI	Central venous catheter-related blood stream infection	PSI 07
Falls and Trauma	Falls that result in severe injury	HAC Falls
SSI ^b	Surgical site infection, mediastinitis, following coronary artery bypass graft (CABG)	HAC CABG
	Surgical site infection following certain orthopedic procedures	HAC Ortho
	Surgical site infection following bariatric surgery for obesity	HAC Bariatric
VTE	Perioperative pulmonary embolism or deep vein thrombosis	PSI 12
Pressure ulcers	Severe pressure ulcers (stage III and above)	PSI 03
Birth trauma	Birth trauma—injury to neonate	PSI 17
Obstetric trauma (with instrument)	Obstetric trauma rate—vaginal delivery with instrument	PSI 18
Obstetric trauma (without instrument)	Obstetric trauma rate—vaginal delivery without instrument	PSI 19

TABLE 1 Inpatient harms

^aThe HAUTI measure is a variation of the HAC CAUTI measure. This measure is the CAUTI measure with an additional ICD-9 code (599.0) for numerator inclusion, which modifies the numerator to include all hospital-acquired urinary tract infections, regardless of whether the infections came from a catheter. This alternate measure was created to address the concern that CAUTIs may be miscoded as simple urinary tract infections in administrative data.²⁸

^bThe SSI measure is a single binary measure that equals one if the patient had an SSI following a CABG, orthopedic, or bariatric surgery procedure.

2.4 | Comparison group selection

To estimate the cost of each medical harm, we needed a counterfactual measure of what hospital costs would have been had the patients not experienced the harm. We constructed a comparison group of stays in which the patients who did not experience a harm but had observed characteristics similar to those who experienced such a harm. We created the comparison group using coarsened exact matching on preselected criteria.¹⁵

We conducted the matching process separately for each type of medical harm and cost measure (index stay costs or 90-day costs). In the first round of matching, we selected any stays without a medical harm as a comparison unit for a stay with a medical harm if they matched exactly on the year of hospitalization, hospital, base diagnosis-related group (which is a diagnosis-related group that has been collapsed to remove distinctions of conditions that occurred with or without a complication), age categories, gender, race categories, whether the patient died, payer type, and admission source. If we could not find a match in the first round, we conducted another round of matching in which the criteria were relaxed—we either loosened or dropped one or more criteria. After the fourth round, we replaced the hospital ID with hospital characteristics, which required matched patients to be in a similar, but not the same, hospital. This iterative process continued, with the matching criteria being relaxed in each subsequent round; see Table S3 for criteria used in each round. We completed the matching (with replacement) in nine rounds and found matches for almost all discharges who experienced a medical harm. Depending on the medical harm measure and cost variable, we matched between 53% and 98% of the discharges who experienced a medical harm in the first round, when matching criteria were most strict. In total, 96%-100% of the discharges who experienced a medical harm were matched to discharges in the same hospital in rounds one through four (see Table S4 for the number of discharges that were matched in each round). Matching within the same hospital addresses most concerns about unobserved hospital differences between the treatment and comparison groups, such as ineffective reporting of POA information or calculation of the cost-to-charge ratios.

Once we selected the comparison group, we conducted balance tests to assess whether the characteristics of patients who experienced a medical harm were similar to those of the comparison group. We find that the matching process substantially decreased the mean standardized bias—the number of standard deviations by which the two sample means differ—to <25% of one standard deviation for all of the characteristics included in the matching process, which is an industry standard for a “good match.”¹⁶ Because of the large number of covariates used in the matching process, we are unable to present the change in the standardized bias for each covariate; however, Table S5 shows that the mean standardized bias across covariates for each type of medical harm and cost measure. Furthermore, in Tables 2 and 3, we show that almost all discharges were matched to comparisons who exactly matched them on most characteristics used in the matching process. For example, across all

inpatient harms, 98%-100% of discharges were matched to comparison that were in the same hospital and shared the same year and base diagnosis-related group code as their match. For six of the 10 inpatient harms, more than 72% of discharges had comparisons that matched along all the characteristics used in the analysis.

2.5 | Regression models

We used linear regression models to estimate the relationship between experiencing a medical harm and the cost of hospital care. The dependent variable in the regression models was either (a) the cost of the index hospital stay or (b) the cost of the index stay plus the costs of stays in the subsequent 90 days. The main independent variable was a dummy variable that indicated whether a medical harm occurred. In addition to estimating the hospital cost of a medical harm, we also calculate the aggregate hospital cost of medical harms across discharges by multiplying the per-discharge hospital cost by the number of discharges that experienced the medical harm in our sample.

Estimating the mean difference in costs between patients who did and did not experience a medical harm may suffer from problems of bias or imprecision, since the cost distribution is skewed and strictly positive; using the log of costs approximately estimates the mean *percentage* difference in costs between the two groups and may have better econometric properties, given the skewed cost distribution.¹⁷

We estimated both models separately for each type of medical harm and cost measure (index stay or 90-day costs). The regression models also controlled for comorbidity measures affiliated with the medical harm of interest (see Table S6); dummies indicating the matching cell(s) into which the patient fell; and other medical harms that occurred (ie, medical harms other than the one of interest). By including dummy variables for each matching cell, we controlled for all variables used during the matching process and all interactions between those variables; as a robustness check, we replaced the matching cell dummies with hospital fixed effects and found very similar results (see Tables S7 and S8). The inclusion of these dummy variables was the primary motivation for estimating a linear regression model as opposed to a nonlinear model (such as a logit or GLM model), which does not allow for the inclusion of fixed effects; however, our large sample sizes make it unlikely that the results would differ between linear and nonlinear models. We used weighted regression analysis to account for variation in size of matching cells and normalized the matched comparison discharges to have the same net weight as those discharges who experienced medical harms in the same matching cell. We calculated standard errors using non-nested two-way clustering¹⁸ to account for a hospital stay's matching cell; if a comparison stay was matched in multiple rounds, we also account for repeated observations.

We also used linear regression models to estimate the relationship between experiencing a medical harm and the probability of a readmission. For this analysis, the regression models and analysis sample were identical to the analysis of 90-day costs except that the dependent variable was replaced with a binary variable

that equaled one if the hospital stay was followed by a readmission within 90 days and equaled zero otherwise. The readmission estimate is the percentage point increase in the probability of a readmission after experiencing an inpatient harm compared to otherwise similar patients who did not experience a harm. Under the assumption that our matching procedure successfully selected a comparison group that reflects the counterfactual readmissions measure had there been no inpatient harm, we can interpret these additional readmissions as being due to the inpatient harm.

2.6 | Limitations

There are several limitations with these analyses. First, as mentioned above, the required data were available in only 12 states, limiting the external validity of these findings. Second, data were missing for some hospital stays. Third, medical harms are measured using PSI and HAC measures, which have been shown to have low sensitivity.^{19,20} Thus, some discharges in the comparison group may have had medical harm, which would attenuate our estimates of the cost of a medical harm. One study¹⁹ showed that the rate of false negatives among cases at risk could be as high as 11% in claims-based data, which is large enough to potentially have a noticeable difference on the estimates. Fourth, our cost measures were based on hospital charges, not the actual amounts paid by patients or their insurers, nor the resources consumed in patients' care. We used the best available charge-to-cost ratios to adjust the cost measures, but our estimates assume a fixed relationship between charges and costs. Although costs would ideally be reported using a more sophisticated bottom-up cost-accounting method calculated separately for each hospital stay and diagnosis, such data are not available. However, using a cost-to-charge ratio is the accepted method for estimating costs and is reasonably accurate for hospital-level estimates.^{21,22} Fifth, medical harms may increase the costs of various types of nonhospital care, including professional fees, pharmaceuticals, durable medical equipment, formal home health care, and time and lost wages of informal caregivers, all which we did not include in our cost measures. Finally, we could not control for unobserved selection bias—it is possible that patients who experienced an in-hospital harm may have had unobserved or unmeasured characteristics that were different than the matched comparison patients who did not experience the medical harm and thus would have experienced higher (or lower) costs regardless of the harms.

3 | RESULTS

There was a wide range in the hospital costs of different types of medical harms. Considering the costs incurred during the index hospital stay, the most expensive medical harms were SSI, catheter-related bloodstream infections (CRBSI), and severe pressure ulcers, which were estimated to increase the cost of the index stay by \$26 000 to \$32 000 more than a comparable hospital stay without those harms (Table 4). In percentage terms, we estimate that an SSI increased the cost of an index stay by

approximately 52%, CRBSI increased costs by approximately 70%, and severe pressure ulcers increased costs of an index stay by 47%. The next tier of medical harms in terms of additional cost were venous thromboembolism (VTE; approximately \$18 000, or 44%); CAUTI (approximately \$13 000, or 46%); hospital-acquired urinary tract infection (HAUTI; \$9000, or 38%); and falls that result in severe injury (\$6000, or 30%). Finally, the additional hospital cost of a birth trauma was relatively low (\$920), as was that of an obstetric trauma (\$103 if no instruments were used and \$176 if instruments were used). All costs estimates were statistically significant.

When considering the aggregate cost of medical harms in the last column of Table 4, it is notable that some of the most expensive ones (namely, SSI and CRBSI) are relatively less common and therefore not as costly at the aggregate level. In contrast, the per-event cost of HAUTI is much lower than the cost of SSI and pressure ulcers, but HAUTI is extremely prevalent; therefore, the aggregate cost of HAUTI in our sample is an order of magnitude more than the aggregate cost of SSI or CRBSI.

Most types of inpatient harms were associated with increased probability of being readmitted to the hospital in the 90 days following the stay when the harm occurred (Table 5). For example, patients with SSI were 10.8 percentage points more likely to have a readmission than matched patients without an infection (27.5% vs 16.7%). Four other types of inpatient harms increased the readmission rate by an estimated three percentage points or more: CAUTI, HAUTI, CRBSI, and falls that result in severe injury.

When we consider all hospital costs in the 90-day follow-up period, our estimated additional hospital costs attributed to a medical harm are similar to, but larger than, our estimated costs accruing in the index stay alone. These estimates, presented in Table 5, account for increases in costs during the index stay resulting from an inpatient harm plus additional costs incurred due to increases in the readmission rate. It is important to note, however, that results in Tables 4 and 5 are not directly comparable because data limitations allowed us to calculate the 90-day costs for only a subset of states.

The 90-day additional hospital costs attributed to SSI and CRBSI events remained highest, at more than \$34 000, whereas the additional costs attributed to pressure ulcers were about \$29 000 over the 90-day period. The corresponding costs attributed to VTE were just over \$21 000; CAUTI and HAUTI were \$18 000 and \$11 000, respectively; and falls were an additional \$8000. Harms related to births and delivery hospital stays had the lowest 90-day additional costs, estimated to be \$1600 for a birth trauma and less than \$200 for obstetric trauma.

4 | CONCLUSIONS

Our findings show substantial range in the additional hospital costs attributed to inpatient harms. The costliest harms, such as SSI,

TABLE 2 Percentage of patients in index stay sample who experienced inpatient harm and were matched to comparison patients with the same characteristics

	CAUTI	HAUTI	CRBSI	Falls and trauma	SSI	VTE	Pressure ulcers	Birth trauma	Obstetric trauma (with instrument)	Obstetric trauma (without instrument)
Year	100	100	100	100	100	100	100	100	100	100
Base DRG code	100	100	100	100	100	100	100	100	100	100
Age category	91.9	92.5	83.6	90.4	89.1	89.7	83.4	99.5	96.5	99.8
Female	91.9	92.5	83.6	90.4	89.1	89.7	83.4	99.5	96.5	99.8
Race (all categories)	89.0	89.2	78.6	88.0	84.7	85.5	78.1	98.6	93.3	99.3
Race (white/not white)	91.9	92.5	83.6	90.4	89.1	89.7	83.4	99.5	96.5	99.8
Died	75.3	75.0	55.3	73.0	66.4	65.9	52.8	95.0	86.2	97.9
Payer type	75.3	75.0	55.3	73.0	66.4	65.9	52.8	95.0	86.2	97.9
Admission source	75.3	75.0	55.3	73.0	66.4	65.9	52.8	95.0	86.2	97.9
Hospital characteristics										
Hospital ID	99.5	99.6	99.5	98.5	99.5	99.1	98.4	99.9	99.5	100
Teaching hospital	99.7	99.8	99.6	99.0	99.7	99.4	99.3	100	99.8	100
State	100	100	100	100	100	100	100	100	100	100
Metro type	99.7	99.8	99.6	99.0	99.7	99.4	99.3	100	99.8	100
Ownership type	99.7	99.8	99.6	99.0	99.7	99.4	99.3	100	99.8	100
Critical access hospital	99.7	99.8	99.6	99.0	99.7	99.4	99.3	100	99.8	100
Number of beds	99.7	99.8	99.6	99.0	99.7	99.4	99.3	100	99.8	100
AHA member	99.5	99.6	99.5	98.6	99.5	99.1	98.5	99.9	99.6	100
Rural referral center	99.5	99.6	99.5	98.6	99.5	99.1	98.5	99.9	99.6	100
IPPS hospital	99.5	99.6	99.5	98.6	99.5	99.1	98.5	99.9	99.6	100
Belongs to health care system	99.5	99.6	99.5	98.6	99.5	99.1	98.5	99.9	99.6	100
Belongs to network	99.5	99.6	99.5	98.6	99.5	99.1	98.5	99.9	99.6	100
Electronic health records	99.5	99.6	99.5	98.6	99.5	99.1	98.5	99.9	99.6	100
Intensivists, as a percentage of total physicians (dummy variables)	99.5	99.6	99.5	98.6	99.5	99.1	98.5	99.9	99.6	100

Note: See Table 1 for inpatient harm measure definitions.

Source: Analysis of HCUP SID data. See Table S1 for list of included states and years.

TABLE 3 Percentage of patients in index stay sample plus 90-day follow-up period who experienced inpatient harm and were matched to comparison patients with the same characteristics

	CAUTI	HAUTI	CRBSI	Falls and trauma	SSI	VTE	Pressure ulcers	Birth trauma	Obstetric trauma (with instrument)	Obstetric trauma (without instrument)
Year	100	100	100	100	100	100	100	100	100	100
Base DRG code	100	100	100	100	100	100	100	100	100	100
Age category	91.4	91.6	82.2	89.5	88.8	88.2	82.9	98.9	95.7	99.7
Female	91.4	91.6	82.2	89.5	88.8	88.2	82.9	98.9	95.7	99.7
Race (all categories)	88.4	88.1	77.6	87.2	84.8	83.7	77.7	97.6	92.3	99.1
Race (white/not white)	91.4	91.6	82.2	89.5	88.8	88.2	82.9	98.9	95.7	99.7
Died	73.9	73.6	53.4	72.1	63.8	63.8	54.5	94.2	84.9	97.5
Payer type	73.9	73.6	53.4	72.1	63.8	63.8	54.5	94.2	84.9	97.5
Admission source	73.9	73.6	53.4	72.1	63.8	63.8	54.5	94.2	84.9	97.5
Hospital characteristics										
Hospital ID	99.3	99.5	99.3	98.1	99.4	98.9	98.6	99.4	99.3	100
Teaching hospital	99.6	99.8	99.5	98.8	99.7	99.2	99.1	99.8	99.8	100
State	100	100	100	100	100	100	100	100	100	100
Metro type	99.6	99.8	99.5	98.8	99.7	99.2	99.1	99.8	99.8	100
Ownership type	99.6	99.8	99.5	98.8	99.7	99.2	99.1	99.8	99.8	100
Critical access hospital	99.6	99.8	99.5	98.8	99.7	99.2	99.1	99.8	99.8	100
Number of beds	99.6	99.8	99.5	98.8	99.7	99.2	99.1	99.8	99.8	100
AHA member	99.3	99.5	99.4	98.3	99.4	98.9	98.7	99.4	99.5	100
Rural referral center	99.3	99.5	99.4	98.3	99.4	98.9	98.7	99.4	99.5	100
IPPS hospital	99.3	99.5	99.4	98.3	99.4	98.9	98.7	99.4	99.5	100
Belongs to health care system	99.3	99.5	99.4	98.3	99.4	98.9	98.7	99.4	99.5	100
Belongs to network	99.3	99.5	99.4	98.3	99.4	98.9	98.7	99.4	99.5	100
Electronic health records	99.3	99.5	99.4	98.3	99.4	98.9	98.7	99.4	99.5	100
Intensivists, as a percentage of total physicians (dummy variables)	99.3	99.5	99.4	98.3	99.4	98.9	98.7	99.4	99.5	100

Note: See Table 1 for inpatient harm measure definitions.

Source: Analysis of HCUP SID data. See Table S1 for list of included states and years.

TABLE 4 Estimated additional hospital cost attributed to an inpatient harms, index stay only

Inpatient harm	Hospital cost for the index stay				Aggregate hospital cost for all index stays	
	Total number of discharges ^a	Discharges with inpatient harm	Mean cost for those without an inpatient harm (\$)	Estimated additional hospital cost attributed to the inpatient harm (\$)	Estimated additional hospital cost attributed to the inpatient harm (as a percentage)	Estimated additional hospital cost attributed to the inpatient harm (\$ million)
CAUTI	151 604	5890	14 743 [22 577]	13 053** (730)	46.1** (1.03)	76.9
HAUTI	4 299 073	287 680	13 926 [23 427]	8712** (81)	38.4** (0.15)	2506.3
CRBSI	94 879	7020	24 444 [48 645]	27 941** (1026)	70.1** (1.11)	196.1
Falls and trauma	287 824	10 778	12 933 [14 618]	6308** (310)	29.8** (0.70)	68.0
SSI	10 759	983	36 253 [41 114]	32 187** (2810)	51.5** (2.63)	31.6
VTE	675 170	37 467	24 379 [37 128]	18 114** (364)	44.3** (0.40)	678.7
Pressure ulcers	21 837	1806	33 127 [51 455]	25 792** (1845)	46.6** (1.92)	46.6
Birth trauma	315 774	8747	3749 [16 855]	920** (302)	5.64** (0.93)	8.0
Obstetric trauma (with instrument)	135 519	24 805	3857 [2548]	103** (13)	3.03** (0.20)	2.6
Obstetric trauma (without instrument)	1 739 127	55 060	3358 [2132]	176** (8)	5.12** (0.13)	9.7

Notes: Standard deviations are in brackets and standard errors are in parentheses. The independent variables included in the cost regressions are a dummy variable for the patient experiencing the inpatient harm of interest; comorbidity measures affiliated with the medical harm of interest (see Table S6); dummies indicating the matching cell(s) into which the patient fell; and dummies indicating other medical harms that occurred (ie, medical harms other than the one of interest). In the fifth column, the estimated costs of inpatient harm, in percentage terms, are coefficients from models in which the logarithm of costs was used as the dependent variable. The measure of costs includes the hospital cost of the index hospital stay but not the cost of any subsequent hospital stays. The last column was computed by multiplying the estimate (in the fourth column) by the number of events in the dataset (the second column). See Table 1 for inpatient harm measure definitions.

^aThe total number of discharges (unweighted) includes discharges who experienced an inpatient harm and satisfy all the sample criteria for the index stay analysis plus their matched comparison discharges.

**Significantly different from zero at the 0.01 level, two-tailed test.

Source: Analysis of HCUP SID data. See Table S1 for list of included states and years.

TABLE 5 Estimated additional hospital cost attributed to an inpatient harm during index stay plus 90-day follow-up period and associated readmission rate

Inpatient harm	Total number of discharges ^a	Readmission rate		Hospital cost for the index stay and any readmissions in 90-day follow-up period			Aggregate hospital cost for all index stays plus 90-day follow-up	
		Discharges with inpatient harm	Mean for those without an inpatient harm (%)	Estimated change in readmission rate from an inpatient harm (percentage points)	Mean for those without an inpatient harm (\$)	Estimated additional hospital cost attributed to the inpatient harm (\$)	Estimated additional hospital cost attributed to the inpatient harm (as a percentage)	Estimated additional hospital cost attributed to the inpatient harm (\$ million)
CAUTI	92 980	3906	29.1	5.8** (0.9)	20 570 [29 660]	18 184** (1508)	47.0** (0.02)	71.0
HAUTI	2 567 415	181 791	26.0	4.4** (0.1)	19 444 [32 098]	11 242** (146)	37.8** (0.00)	2043.7
CRBSI	59 291	4462	32.4	6.3** (1.0)	35 182 [67 573]	34 798** (1701)	69.6** (0.02)	155.3
Falls	169 792	6849	24.1	3.1** (0.7)	17 720 [22 777]	8378** (602)	29.9** (0.01)	57.3
SSI	6355	618	16.7	10.8** (2.6)	42 843 [53 207]	34 390** (4140)	52.1** (0.04)	21.3
VTE	359 625	22 231	20.0	2.9** (0.4)	29 312 [44 473]	21 222** (579)	44.2** (0.01)	471.8
Pressure ulcers	12 397	1038	35.3	2.8 (1.9)	42 920 [59 718]	28 968** (2828)	41.5** (0.03)	30.0
Birth trauma	60 456	1806	3.0	-0.3 (0.5)	4308 [18 949]	1599* (722)	7.35** (0.02)	2.9
Obstetric trauma (with instrument)	73 913	13 947	1.5	0.05 (0.14)	3939 [2857]	149** (37)	3.35** (0.00)	2.1
Obstetric trauma (without instrument)	953 081	31 408	1.3	0.3** (0.08)	3391 [2719]	183** (14)	5.39** (0.00)	5.7

Notes: Standard deviations are in brackets and standard errors are in parenthesis. The independent variables included in the cost and readmissions regressions are a dummy variable for the patient experiencing the inpatient harm of interest; comorbidity measures affiliated with the medical harm of interest (see Table S6); dummies indicating the matching cell(s) into which the patient fell; and dummies indicating other medical harms that occurred (ie, medical harms other than the one of interest). In the final column, the estimated costs of inpatient harms, in percentage terms, are coefficients from models in which the logarithm of costs was used as the dependent variable. The measure of readmissions was a binary variable that equaled one if the hospital stay was followed by a readmission within 90 d and equaled zero otherwise. The last column was computed by multiplying the estimate (in the sixth column) by the number of events in the dataset (the second column). The measure of costs includes the hospital cost of the index hospital stay plus any subsequent hospital stays occurring within 90 d. See Table 1 for inpatient harm measure definitions.

^aThe total number of discharges (unweighted) includes discharges who experienced an inpatient harm and satisfy all the sample criteria for the index stay plus 90-day follow-up period analysis plus their matched comparison discharges.

*Significantly different from zero at the 0.05 level, two-tailed test.

**Significantly different from zero at the 0.01 level, two-tailed test.

Source: Analysis of HCUP SID data. See Table S1 for list of included states and years.

severe pressure ulcers, and CRBSI, can add \$26 000 to \$30 000 (or between 47% to 70%) to the cost of the hospital index stay. Even the less costly medical harms, such as CAUTI, HAUTI, VTE, and falls that result in severe injury, can add anywhere from \$6000 to \$18 000 (or between 30% to 50%) to the cost of the index stay. The lowest cost harms were birth and obstetric traumas, which ranged from between \$100 and \$200 for obstetric traumas without instruments to \$920 for birth traumas. Some of the costliest harms per event, such as SSI and CRBSI, are relatively less common and therefore have a lower aggregate cost than do medical harms such as HAUTI, which is less costly per event but extremely prevalent in our sample. Furthermore, some inpatient harms also led to increased risk of a re-admission, thereby increasing the likelihood of costly stays following the original stay during which the harm occurred.

Despite major differences between our analysis and previous studies in the types of data used, time periods covered (which may cause differences in cost estimate magnitudes due to inflation), and methods of detection and definitions of harms, our cost estimates were generally consistent with those developed by others.² Our cost estimate for SSI (\$32 000) was similar in magnitude to the existing estimates that range from \$20 785 to \$34 671.^{7,23} Our estimate for central venous CRBSI (approximately \$28 000) was on the low end of existing estimates of \$39 000, \$83 000, \$46 000, and \$29 000,^{7,10,13,23} but our estimate for severe pressure ulcers (approximately \$26 000 per event) was somewhat higher than existing estimates of that range from \$8000 to \$11 000.^{8,10,13} The difference between our cost estimate for severe pressure ulcers and two of the existing estimates^{10,13} may be because our analysis incorporated the introduction of the POA indicator, while differences with the third pressure ulcer cost estimate⁸ may be because they only examined surgical pressure ulcers and the cost of the surgical stay. Our \$13 000 cost estimate for CAUTI was in the middle of a wide range of other estimates, which ranged from \$362 to almost \$25 000.^{7,10,23} Finally, our estimates for our three birth and obstetric harms (from \$103 to \$920 per event) were roughly on the same order of magnitude as the existing estimates that range from \$93 to \$298.¹³

Our analysis represents the rigorous estimates of the hospital costs of a variety of inpatient harms for a large sample of patients. Our approach to estimating the cost of inpatient harms incorporates novel and important features, such as an extensive approach to creating a comparison group through coarsened exact matching, the use of a POA indicator when identifying medical harms, and the inclusion of patients covered by all payers. Our analysis also extends beyond the cost of the index admission to examine the cost of hospital readmissions up to 90 days after the index discharge.

These estimates should be of interest to a range of health care administrators and policy makers. Given that Medicare will no longer reimburse for these types of HACs, hospital administrators are concerned about the high cost of inpatient harms. Our finding that inpatient harms cause higher readmissions rates has implications for bundled payment and other payment and delivery models where the cost of readmissions falls fully or partly on the hospitals.

Policy makers could use these estimates to identify areas for cost savings to the health care system resulting from improvements in the quality of care. There have been recent initiatives to reduce the number of medical harms that occur in hospitals in the United States. For example, Partnership for Patients and the Hospital Improvement Innovation Network are public-private partnerships sponsored by HHS and led by CMS to improve the quality, safety, and affordability of health care for all Americans, in part by reducing all-cause harm in acute care hospitals. The HAC Reduction Program, which began in 2015, incentivizes hospitals to reduce HACs by adjusting payments based on their risk-adjusted HAC quality measure. There have been other large-scale efforts, from the 100 000 Lives Campaign, which operated from January 2005 to June 2006,²⁴ to efforts by state governments and payers.²⁵⁻²⁷ An important area for future research would be to estimate the impact of these initiatives on the occurrence of medical harms, and the cost estimates produced by our study provide a benchmark for potential savings in hospital costs that would occur if these types of initiatives are successful. Reductions in additional nonhospital costs incurred after discharge as a result of these inpatient harms raise the stakes even further. Finally, our analysis and discussion have focused on costs to hospitals and payers, but these inpatient harms also have consequences on patients' health and quality of life, which we did not measure and would be another area for future research.

ACKNOWLEDGMENTS

Joint Acknowledgment/Disclosure Statement: The authors would like to thank Suzie Witmer for managing the database construction process; Swaati Bangalore, Justin Vigeant, and Haixia Xu for database construction and programming; Sarah Schoenfeldt, Bryan Bernecker, and Andrew Yen, who also provided helpful programming and research assistance; and Valerie Cheh, Sue Felt-Lisk, Catherine McLaughlin, Neil McCray, and Jelena Zurovac, who provided useful comments and suggestions. This analysis was funded by the Center for Medicare and Medicaid Innovation, Contract No. GS-10F-0166R. The statements contained herein are those of the authors and do not necessarily reflect the views or policies of the Center for Medicare and Medicaid Innovation.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Anand P, Kranker K, Chen AY. Estimating the hospital costs of inpatient harms. *Health Serv Res*. 2019;54:86-96. <https://doi.org/10.1111/1475-6773.13066>