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Risk of readmissions, mortality, and hospital-acquired conditions across hospital-acquired pressure injury (HAPI) stages in a US National Hospital Discharge database

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Abstract

Pressure injuries are one of the most common and costly complications occurring in US hospitals. With up to 3 million patients affected each year, hospital-acquired pressure injuries (HAPIs) place a substantial burden on the US healthcare system. In the current study, US hospital discharge records from 9.6 million patients during the period from October 2009 through September 2014 were analysed to determine the incremental cost of hospital-acquired pressure injuries by stage. Of the 46 108 patients experiencing HAPI, 16.3% had Stage 1, 41.0% had Stage 2, 7.0% had Stage 3, 2.8% had Stage 4, 7.3% had unstageable, 14.6% had unspecified, and 10.9% had missing staging information. In propensity score-adjusted models, increasing HAPI severity was significantly associated with higher total costs and increased overall length of stay when compared with patients not experiencing a HAPI at the index hospitalisation. The average incremental cost for a HAPI was $21 767. Increasing HAPI severity was significantly associated with greater risk of in-hospital mortality at the index hospitalisation compared with patients with no HAPI, as well as 1.5 to 2 times greater risk of 30-, 60-, and 90-day readmissions. Additionally, increasing HAPI severity was significantly associated with increasing risk of other hospital-acquired conditions, such as pneumonia, urinary tract infections, and venous thromboembolism during the index hospitalisation. By preventing pressure injuries, hospitals have the potential to reduce unreimbursed treatment expenditures, reduce length of stay, minimise readmissions, prevent associated complications, and improve overall outcomes for their patients.

KEYWORDS

costs, healthcare resource utilization, hospital acquired pressure injuries, mortality

1 | INTRODUCTION

In the US, pressure injuries affect between 1.3 and 3 million adults,[1] with an estimated incidence ranging from 0.4% to 12%,[2] depending on the care setting. Pressure injuries are associated with higher rates of mortality[3,4] and decreased quality of life.[4,5] Risk factors for pressure ulcers include age, prolonged hospitalisation, a variety of

cognitive and physical impairments, as well as other comorbid conditions such as immobility, incontinence, and malnutrition.[1,6-8] The Braden Scale is a tool standardly used by hospitals to identify patients at risk for hospital-acquired pressure injuries (HAPIs). The Braden Score is calculated based on a patient's perceived level of sensory perception, moisture, activity, mobility, nutrition, and friction and shear[9]; however, its reliability has been called into question.[3,10,11]

Estimates of the economic burden of HAPIs vary widely.[2,4,6,7,12] However, the burden appears to be steadily growing over time, with the Agency for Healthcare Research and Quality (AHRQ) estimating HAPI costs at $10 billion a year, while other cost estimates indicating costs in the US may exceed $26.8 billion (2016 US dollars),[12] of which approximately 59% of this estimate is disproportionately attributed to the most severe HAPIs, Stage 3 and Stage 4.[12] Stage 3 indicates "a full thickness tissue loss where subcutaneous fat may be visible, but bone, tendon or muscles are not exposed", while Stage 4 is where "full thickness tissue loss with exposed bone, tendon or muscle" occurs.[2] In addition to the direct treatment costs, pressure injuries negatively impact hospital quality metrics and can increase liability exposure.[12,13] Beyond the financial implications, pressure injuries have a negative impact on a patient's quality of life. In response to the increasing burden of HAPIs, in 2008 the Centers for Medicare and Medicaid Services (CMS) deemed HAPIs preventable in most circumstances, and penalised hospitals for Stage 3 and 4 HAPIs.[2,3,14] Further, in 2015, CMS instituted a 1% Medicare reimbursement penalty for hospitals ranking in the bottom quartile for hospital-acquired conditions.[3]

The prevention of HAPIs involves frequent patient turning and repositioning, use of heel protectors or suspension devices, use of prophylactic foam dressings on high-risk skin areas and appropriate bed support surfaces, as well as multidisciplinary team approaches,[1,2,6,8,11,15-17] and these strategies can be adapted to the care setting.[1] However, despite efforts to prevent HAPIs, national rates continue to increase. According to the AHRQ's 2019 National Scorecard on Hospital-Acquired Conditions, pressure injuries are the only hospital-acquired condition that has increased in prevalence over 2014 baseline rates (https://www.ahrq.gov/data/infographics/hac-rates_2019.html).

Previous work was undertaken by our team to determine the risk factors underlying HAPIs, as well as estimate the economic burden caused by HAPIs in the United States, based on an analysis of approximately 17 million inpatients in the Premier Healthcare Database (PHD).[7] The current study expands upon this previous study by examining the cost and healthcare resource utilisation of HAPIs by stage, as well as assessing the associations between HAPIs and in-hospital mortality, length-of-stay, and risk of readmission. Furthermore, this study examines the association between HAPI stages and other hospital-acquired conditions, such as ventilator-acquired pneumonia (VAP), falls, urinary tract infections (UTIs), and venous thromboembolism (VTE).

Key Messages

- Pressure injuries are one of the most common and costly complications occurring in US hospitals. With up to 3 million patients affected each year, hospital-acquired pressure injuries (HAPIs) place a substantial burden on the US healthcare system.
- This study examined associations of HAPIs by stage with hospital-acquired conditions, in-hospital mortality, costs, and healthcare resource utilisation among 9.6 million patients from October 2009 through September 2014 using a US hospital discharge database.
- Increasing HAPI severity was significantly associated with higher risk of in-hospital mortality and hospital-acquired conditions as well as higher costs and greater resource utilisation at the index hospitalisation. The average incremental cost for a HAPI was $21,767. Higher risk of 30-, 60-, and 90-day readmissions was also observed.

2 | METHODS

2.1 | Study population

The PHD is a US national hospital discharge database which at the time of the current study (October 2009 through September 2014), had more than 6 million annual hospital discharges from more than 600 geographically diverse hospitals. The PHD is a service-level, all-payer database that contains information on inpatient and hospital-based outpatient discharges, including standard hospital discharge files, with a patient's demographic and disease state, and information on billed services, including medications, laboratory tests performed, diagnostics, and therapeutic services, in statistically de-identified patient daily service records. Hospital characteristics of bed size, population served (rural vs urban), geographic location, and teaching status were

also available. Patients are tracked with a unique identifier across visits to the same facility. The database complies with the Health Insurance Portability and Accountability Act (HIPAA) of 1996.

For this retrospective observational study, patients were included if they were aged ≥18 years with an inpatient hospital discharge in the PHD between October 1, 2009 and September 30, 2014. This was designated as the index hospitalisation. Patients were excluded from this analysis if they were missing demographic information (age, race, or gender), had a length of stay (LOS) < 3 days, or total hospitalisation costs < $1500 before inflation adjustment. These exclusion criteria were chosen due to the time required to develop, diagnose, and treat a HAPI, coupled with the fact that pressure injuries identified very early in the hospitalisation are more likely to be present on admission.

2.2 | Hospital-acquired pressure injuries

Presence, location, and staging for HAPI were defined using ICD-9 codes 707.00 to 707.09 and 707.20 to 707.25. The HAPI had to be hospital-acquired (e.g. developed during the index hospitalisation). For the purposes of classification, a hierarchical approach was used for patients with more than one HAPI, whereby the most severe HAPI was considered the primary cost driver. For patients with more than one HAPI, where staging information was present (e.g. Stage 1-4), the most severe stage was used for analysis. In cases where a patient had one HAPI with missing stage information but one or more other HAPIs with stages (e.g. Stage 1-4, unspecified, unstageable), the highest stage (e.g. Stage 1-4) or the stage where there was additional information (e.g. unspecified, unstageable) was used. In cases where a patient had an unstageable HAPI, but one or more other HAPI with stages noted, the unstageable HAPI designation was used if the other HAPIs noted were Stage 1 or 2; if the other HAPIs noted were Stage 3 or 4, then that information was used.[18]

2.3 | Comorbid conditions and covariates

The Charlson Comorbidity Index (CCI) was calculated using previously described methodology.[19] Several additional comorbid conditions and risk factors beyond the CCI were also of interest as they have previously been shown to impact the development of HAPI, and these included immobility, urinary or bowel incontinence, chronic kidney disease, congestive heart failure, dementia, diabetes, malnutrition, moisture associated dermatitis, neoplasm, neuropathy, history of HAPI, shock, vasopressor use, anaemia, fluid and electrolyte disorders, sepsis, history of diabetic ulcers of the lower limb, quadriplegia/hemiplegia, unstable spine, and obstructive sleep apnea. ICD-9 codes were used to define these comorbidities; in the case of immobility and vasopressor use, text searches of the hospital charge master were used. A list of risk factors with additional details is provided in the Supplementary Materials.

Other covariates included age, race, and gender, as well as admission source (home; emergency department; transfer from skilled nursing facility (SNF), rehab or intermediate care facility (ICF); transfer from an acute care facility; other), discharge status (expired; home; SNF, rehab or ICF; transferred to acute care facility; other), provider area (Midwest, Northeast, South, West), and whether the patient had any days of ICU stay during the index hospitalisation. Additionally, major diagnostic categories (MDC) were defined using CMS criteria.

2.4 | Outcomes

Presence of an all-cause 30-, 90-, or 180-day readmission (from the time of the index hospitalisation) was assessed, as well as in-hospital mortality at index hospitalisation. Several hospital-acquired conditions were also of interest, including acute respiratory distress syndrome (ARDS), pneumonia, ventilator-associated pneumonia (VAP), falls, urinary tract infection (UTI), and venous thromboembolism (VTE), as well as osteomyelitis and sepsis. These conditions were not present on admission at the time of the index hospitalisation and were defined using ICD-9 codes (see Supplementary Materials).

Total costs were calculated and included all services, medications, and supplies billed during the index hospitalisation. Total costs were calculated both overall and among patients with any days of intensive care unit (ICU) stay. Costs were inflation-adjusted to 2014 US dollars using the U.S. Department of Labor Consumer Price Index-All Urban Consumers data. Length of stay (LOS) similarly was calculated for the index hospitalisation, both overall and among patients with any days of ICU stay.

2.5 | Statistical analysis

Summary descriptive statistics (mean and standard deviations for continuous variables, and percentages for categorical variables) were calculated. Propensity scores were generated using logistic regression models with HAPI yes/no as the outcome, and the following as independent

variables: age, gender, race, primary payer, admission source, anaemia, malnutrition, fluid and electrolyte disorders, Charlson comorbidity index, immobility, quadriplegia/hemiplegia, neuropathy, urinary incontinence, congestive heart failure, chronic kidney disease, dementia, diabetes, unstable spine present on admission, unstable spine *not* present on admission, shock without trauma present on admission, shock without trauma *not* present on admission, use of vasopressors, moisture-associated dermatitis, diabetic ulcers of the lower limb, history of pressure ulcer in the previous year, pressure ulcer present on admission, malignant neoplasm, sepsis present on admission, obstructive sleep apnea, and MDC categories. Details on ICD codes used to define these conditions can be found in the Supplementary Materials.

Relative risk regression with robust standard errors was used for readmissions, mortality, and hospital-acquired conditions outcomes. Readmissions models did not include patients who expired during the index hospitalisation. In-hospital mortality and hospital-acquired conditions were assessed during index hospitalisation, while readmissions were assessed up to 180 days post-index discharge. Generalised linear models with gamma distribution and log link, and negative binomial distribution with log link were used for cost and length of stay calculation at the index hospitalisation, respectively. Models were adjusted for propensity scores, provider area, and discharge status. Patients with missing propensity scores were not included in the multivariate models.

The average incremental cost of a HAPI (i.e. average HAPI cost across all stages) was calculated by multiplying the additional cost above and beyond non-HAPI patients for each HAPI stage by a weighting factor equal to the proportion of HAPIs in each stage. The weighted cost for each stage was then summed to determine the average total incremental cost for a HAPI.

3 | RESULTS

3.1 | Patient characteristics at index hospitalisation

A total of 9 677 061 patients were included in the study, of whom 46 108 (0.47%) developed a HAPI during the index hospitalisation. Of the 46 108 HAPI patients, 7503 (16.3%) were Stage 1, 18 901 (41.0%) Stage 2, 3242 (7.0%) Stage 3, 1310 (2.8%) Stage 4, 3358 (7.3%) unstageable, 6754 (14.6%) unspecified and 5040 (10.9%) patients had missing information for stage (Table 1). Patients with Stage 4 HAPIs had higher percentages of quadriplegia/hemiplegia, shock, sepsis, history of previous pressure ulcer, and malnutrition compared with patients in other HAPI stages. Percentages of patients with any days of ICU stay during the index hospitalisation differed across HAPI stages as well, with the highest in Stage 4 (65%) and the lowest in Stage 1 (39%). Average propensity scores were also highest in the Stage 4 HAPI group (0.123) and lowest in Stage 1 (0.036).

3.2 | Hospital-acquired and other conditions at index hospitalisation

Among patients with HAPI, acute respiratory distress syndrome (ARDS) and pneumonia were the most frequent comorbid conditions, with 17.6% experiencing ARDS during their index hospital stay and 16.4% experiencing pneumonia. Sepsis and UTIs were also relatively frequent at 13.7% and 13.8%, respectively. Only a small percentage of patients with HAPI experienced falls (0.88%), although patients with HAPI were more likely to fall than patients without HAPI. For all hospital-acquired conditions except falls, Stage 4 HAPI patients had the highest frequency (Table 2); the unstageable patients had the highest percentages of falls (1.3%). Falls were the least frequent of all HAPI stages for Stage 4 and patients with missing HAPI stage (both 0.4%). Sepsis, pneumonia, ARDS, and UTIs were especially common among Stage 4 HAPI patients (all >25%) (Table 2).

When models were adjusted for propensity score, provider area, and discharge status, HAPI stage was significantly associated with an increased risk of pneumonia, VAP, UTI, and VTE compared with patients with no HAPI, and in a dose–response fashion across increasing stages of HAPI severity (Table 3). The dose–response was particularly pronounced for VAP, ranging from an approximately 3 times increased risk for HAPI Stage 1 up to almost 12 times the risk for HAPI Stage 4 patients compared with patients with no HAPI. HAPI stages were also associated with increased risk of ARDS and sepsis, but the risk was relatively flat across increasing HAPI stages (Table 3). There was a significantly increased risk of falls for patients with HAPI Stages 1, 2, 3, and unstageable, but not for patients with HAPI Stage 4, or unspecified or missing HAPI stage. HAPI was not significantly associated with the development of osteomyelitis during hospitalisation.

3.3 | Readmissions

Among patients with a HAPI, 25.5% were readmitted by 30 days, 36.6% by 90 days, and 42.7% by 180 days; these unadjusted percentages did not differ substantially across

TABLE 1 Patient characteristics by HAPI stage at index hospitalisation[a]

	No HAPI	HAPI Stage 1	HAPI Stage 2	HAPI Stage 3	HAPI Stage 4	Unstageable	Unspecified	Missing
	n = 9 630 953	n = 7503	n = 18 901	n = 3242	n = 1310	n = 3358	n = 6754	n = 5040
Age	58 ± 21	73 ± 15	70 ± 15	67 ± 16	63 ± 16	69 ± 15	69 ± 15	69 ± 16
Female sex	60%	52%	49%	43%	43%	45%	48%	49%
Race								
Caucasian	66%	75%	65%	61%	55%	70%	70%	62%
African-American	13%	7%	15%	19%	24%	13%	13%	19%
Other	21%	18%	20%	20%	22%	17%	17%	20%
Hispanic ethnicity	7%	5%	8%	5%	5%	6%	6%	8%
Primary payor								
Commercial	29%	12%	13%	14%	16%	13%	14%	13%
Medicaid	14%	7%	10%	15%	18%	10%	10%	11%
Medicare	47%	76%	72%	64%	59%	71%	70%	71%
Other	10%	4%	5%	7%	7%	5%	6%	4%
ICU stay[b]	16%	39%	47%	59%	65%	56%	45%	47%
Discharge status								
Expired	2%	9%	13%	16%	22%	18%	12%	13%
Home	75%	28%	24%	19%	16%	19%	25%	22%
SNF/Rehab/ ICF/LTC	15%	45%	45%	46%	45%	44%	44%	46%
Transferred	5%	10%	11%	11%	10%	10%	11%	10%
Other	3%	8%	7%	8%	8%	8%	8%	8%
CCI	1.5 ± 2.0	3.1 ± 2.6	3.4 ± 2.7	3.6 ± 2.8	3.3 ± 2.6	3.4 ± 2.6	3.3 ± 2.7	3.0 ± 2.5
Quadri-/ hemiplegia	2%	6%	7%	10%	17%	8%	8%	11%
Sepsis	6%	24%	31%	42%	55%	39%	31%	33%
Chronic kidney Dis.	12%	31%	36%	37%	39%	38%	35%	33%
Heart failure	12%	35%	36%	36%	33%	37%	34%	36%
Diabetes	24%	37%	43%	43%	44%	46%	43%	36%
Immobility	1%	6%	7%	7%	9%	6%	7%	8%
Urinary incontinence	3%	8%	7%	7%	6%	6%	8%	7%
Bowel incontinence	0.1%	0.2%	0.3%	0.2%	0.5%	0.1%	0.3%	0.3%
History of PU	0.3%	6%	6%	9%	16%	7%	8%	14%
Dementia	6%	17%	15%	12%	11%	15%	15%	14%
Dermatitis	0.4%	0.8%	1%	0.9%	0.8%	0.8%	0.9%	0.6%
Malnutrition	4%	27%	31%	40%	47%	34%	31%	33%
Shock	2%	12%	17%	27%	32%	24%	16%	19%
Propensity score	0.004 ± 0.015	0.036 ± 0.080	0.052 ± 0.101	0.082 ± 0.136	0.123 ± 0.160	0.063 ± 0.116	0.052 ± 0.109	0.056 ± 0.109

Abbreviations: CCI, Charlson comorbidity index; ICF, intermediate care facility; LTC, long-term care; PU, pressure ulcer; SNF, skilled nursing facility.

[a]Percentages except for age, CCI and propensity score, which are mean ± SD.

[b]Among patients with any days of ICU stay during the index hospitalisation.

TABLE 2 Frequency of hospital acquired conditions, readmissions, and in-hospital mortality by HAPI stage

	No HAPI (%)	HAPI Stage 1 (%)	HAPI Stage 2 (%)	HAPI Stage 3 (%)	HAPI Stage 4 (%)	Unstageable (%)	Unspecified (%)	Missing (%)
	n = 9 630 953	n = 7503	n = 18 901	n = 3242	n = 1310	n = 3358	n = 6754	n = 5040
Hospital Acquired and Other Conditions[a]								
ARDS	2.0	12.2	17.5	23.9	27.0	21.9	16.4	17.8
Pneumonia	1.6	11.1	16.4	23.8	31.9	19.1	15.0	15.5
VAP	0.1	0.7	1.5	3.3	6.4	2.5	1.0	1.6
Osteomyelitis	0.4	3.7	6.5	12.4	19.1	9.4	5.9	7.6
Sepsis	0.9	7.9	13.3	22.1	30.6	16.4	12.3	14.4
Falls	0.2	1.0	1.0	1.0	0.4	1.3	0.6	0.4
UTI	1.7	11.0	13.5	19.7	25.3	15.3	12.5	12.9
VTE	0.7	4.9	7.6	11.0	13.2	8.9	7.1	7.0
Readmissions[b] *and Mortality*								
All-cause 30-day	10.8	24.4	26.1	25.8	25.5	25.6	24.3	26.6
All-cause 90-day	16.7	34.9	37.1	37.0	39.7	37.2	35.1	38.2
All-cause 180-day	21.2	41.4	43.3	41.9	43.9	42.2	41.5	44.2
Mortality[a]	1.8	9.2	12.8	16.4	21.7	18.1	12.3	13.5

Abbreviations: ARDS, acute respiratory distress syndrome; UTI, urinary tract infection; VAP, ventilator associated pneumonia; VTE, venous thromboembolism.
[a]At the index hospitalisation.
[b]Readmissions percentages are *among those who did not expire during the index hospitalisation*.

HAPI stages but were much higher than in patients without HAPI (Table 2). Similarly, while all HAPI stages had a significantly increased risk of readmissions at 30, 90, and 180 days in adjusted models compared with the no HAPI group, these risks were rather flat across the HAPI stages, ranging from approximately 1.3 to 2.0 (Table 3). Readmissions among patients with any days of ICU stay at the index hospitalisation exhibited similar results (data not shown).

3.4 | Mortality

The overall unadjusted mortality rate among HAPI patients at the index hospitalisation was 13.1%. Patients in all HAPI stages had a substantially higher risk of mortality compared with the no HAPI group (Table 2). Stage 4 HAPI patients had the highest unadjusted mortality percentage (21.7%), followed by patients with unstageable (18.1%), Stage 3 (16.4%), missing HAPI stage (13.5%), Stage 2 (12.8%), unspecified stage (12.3%), and then Stage 1 (9.2%) (Table 2). In adjusted models, there was substantially increased risk of mortality at the index hospitalisation among patients with HAPI compared with no HAPI, ranging from 4 times higher risk in patients with HAPI Stage 1 to more than 6 times greater risk in patients with an unstageable HAPI (Table 3). Patients with Stage 4 HAPIs had approximately 5 times higher risk of mortality (Table 3). Among patients who had any ICU stay during the index hospitalisation, risk of mortality was also higher for all HAPI stages compared with the non-HAPI control group, although the magnitude was smaller with relative risks ranging from 1.36 in the unspecified HAPI group to 1.88 in the unstageable HAPI group; all stages still had significantly increased mortality risk compared with non-HAPI control patients (data not shown).

3.5 | Cost and length of stay during index hospitalisation

Increasing average adjusted total costs were observed across HAPI stages, with the unstageable, unspecified, and missing HAPI stage groups falling in the middle (average total costs $40 000-$45 000) (Figure 1). The overall highest mean adjusted total costs were for Stage 4 HAPI patients ($67 198) followed by Stage 3 HAPI patients ($54 151), while the average cost for the no HAPI group was $20 684 (Figure 1). Among patients with any days of ICU stay at the index hospitalisation, total costs followed a similar trend, although the total costs among patients with any days of ICU stay were higher in each HAPI group compared with the overall total costs in each HAPI group (Figure 1).

Incremental adjusted total costs among patients with any HAPI are displayed in Table 4. Overall, a hospital-

TABLE 3 Association of HAPI by stages with hospital acquired conditions, readmissions, and in-hospital mortality[a]

	HAPI Stage 1	HAPI Stage 2	HAPI Stage 3	HAPI Stage 4	Unstageable	Unspecified	Missing
	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
	n = 6931	n = 17 172	n = 2905	n = 1207	n = 3106	n = 6204	n = 4705
Hospital Acquired and Other Conditions[b]							
ARDS	1.47 (1.34, 1.62)	1.50 (1.42, 1.58)	1.35 (1.19, 1.53)	1.39 (1.23, 1.58)	1.30 (1.15, 1.46)	1.40 (1.28, 1.54)	1.49 (1.36, 1.64)
Pneumonia	2.47 (2.25, 2.70)	2.88 (2.74, 3.04)	2.85 (2.48, 3.27)	3.41 (2.99, 3.88)	2.48 (2.13, 2.88)	2.42 (2.18, 2.68)	2.59 (2.29, 2.91)
VAP	3.10 (2.20, 4.38)	5.78 (4.90, 6.81)	6.96 (5.07, 9.55)	11.75 (8.66, 15.93)	6.26 (4.52, 8.68)	3.29 (2.22, 4.87)	4.35 (3.08, 6.16)
Osteomyelitis	1.13 (0.85, 1.50)	1.14 (0.98, 1.32)	1.02 (0.77, 1.35)	1.14 (0.81, 1.63)	0.94 (0.70, 1.27)	0.86 (0.62, 1.19)	1.10 (0.79, 1.54)
Sepsis	1.31 (1.06, 1.58)	1.49 (1.35, 1.66)	1.21 (0.95, 1.53)	1.35 (1.01, 1.80)	1.07 (0.79, 1.44)	1.16 (0.93, 1.45)	1.30 (0.96, 1.77)
Falls	2.27 (1.75, 2.95)	2.12 (1.79, 2.51)	2.00 (1.34, 2.99)	0.81 (0.30, 2.20)	2.75 (1.95, 3.88)	1.32 (0.91, 1.91)	0.77 (0.45, 1.30)
UTI	3.05 (2.83, 3.29)	3.53 (3.38, 3.69)	3.94 (3.58, 4.32)	4.67 (4.14, 5.26)	3.56 (3.24, 3.92)	3.09 (2.86, 3.34)	3.13 (2.87, 3.41)
VTE	2.87 (2.53, 3.25)	3.74 (3.49, 4.00)	4.11 (3.57, 4.73)	4.23 (3.50, 5.13)	3.77 (3.26, 4.36)	3.49 (3.11, 3.91)	3.24 (2.83, 3.71)
Readmissions and Mortality[b]							
All-cause 30-day	2.00 (1.90, 2.10)	1.98 (1.92, 2.05)	1.69 (1.54, 1.85)	1.51 (1.31, 1.74)	1.83 (1.69, 1.99)	1.82 (1.72, 1.93)	1.96 (1.84, 2.10)
All-cause 90-day	1.85 (1.77, 1.93)	1.83 (1.78, 1.88)	1.58 (1.46, 1.71)	1.42 (1.26, 1.61)	1.78 (1.63, 1.87)	1.70 (1.61, 1.78)	1.81 (1.71, 1.91)
All-cause 180-day	1.73 (1.67, 1.80)	1.69 (1.65, 1.73)	1.42 (1.32, 1.52)	1.28 (1.14, 1.44)	1.56 (1.47, 1.66)	1.59 (1.52, 1.66)	1.66 (1.58, 1.75)
Mortality	4.09 (3.72, 4.50)	5.09 (4.82, 5.38)	5.36 (4.72, 6.08)	5.75 (4.86, 6.80)	6.67 (5.99, 7.42)	4.56 (4.11, 5.06)	4.89 (4.38, 5.45)

Abbreviations: ARDS, acute respiratory distress syndrome; UTI, urinary tract infection; VAP, ventilator associated pneumonia; VTE, venous thromboembolism.

[a]Relative risk regression model with robust standard errors that adjusted for propensity score and provider area (midwest, west, south, northeast); note that discharge status is quite collinear with readmissions and mortality due to the sample (e.g. readmissions among those who did not expire when expire is a category of discharges) so mortality and readmissions models adjust for propensity score and provider area only. *No HAPI (n = 9 355 000) is the reference group. Patients with missing propensity scores were not included in the multivariate models.*

[b]Readmissions models do not include patients who expired during the index hospitalisation; In-hospital mortality and hospital acquired conditions during index hospitalisation, no follow up time.

acquired pressure injury incrementally added $21 767 to the cost of the hospitalisation. Among patients requiring ICU care, a HAPI incrementally added $32 292 to the cost of the hospitalisation.

Increasing average adjusted length of stay (LOS) was observed overall as well as among patients with any days of ICU stay. Similarly, the unstageable, unspecified, and missing HAPI groups fell in the middle of the LOSs (Figure 2). The longest LOS among patients in the overall sample was Stage 4 HAPI patients (30.1 days), followed by Stage 3 patients (21.2 days), while the average LOS for the non-HAPI control group was 7.4 days (Figure 2).

4 | DISCUSSION

In a sample of approximately 9.6 million patients (46 108 with HAPI) from a US hospital discharge database, HAPIs were found to significantly increase cost of care and were significantly associated with the presence of other hospital-acquired conditions during the index hospitalisation. Overall, the development of a HAPI independently added $21 767 to the cost of the hospitalisation. In terms of associations with other hospital-acquired conditions, there was a strong dose–response pattern whereby increasing HAPI stages were significantly associated with increased risk of pneumonia, VAP, UTI, and VTE during the index hospitalisation. Falls exhibited a somewhat different pattern than other hospital-acquired conditions, with no increased risk in Stage 4 HAPI patients. It is hypothesised that many of the Stage 4 HAPI patients may be predominately bedridden, and thus have a lower risk for falls. It should be noted that this retrospective observational study has identified associations between HAPIs and other HACs, which does not imply causation.

Patients with HAPIs had significantly higher in-hospital mortality rates across stages, as well as higher risk of readmissions at 30-, 90-, and 180-days post index hospitalisation, compared with patients without HAPI. Although these results held for patients with any days of ICU stay, the increased risk of mortality was not as high as in the overall sample, which may be due to the increased similarity of disease burden or severity in patients with and without HAPI who spend time in the ICU. In other words, given that mortality rates are

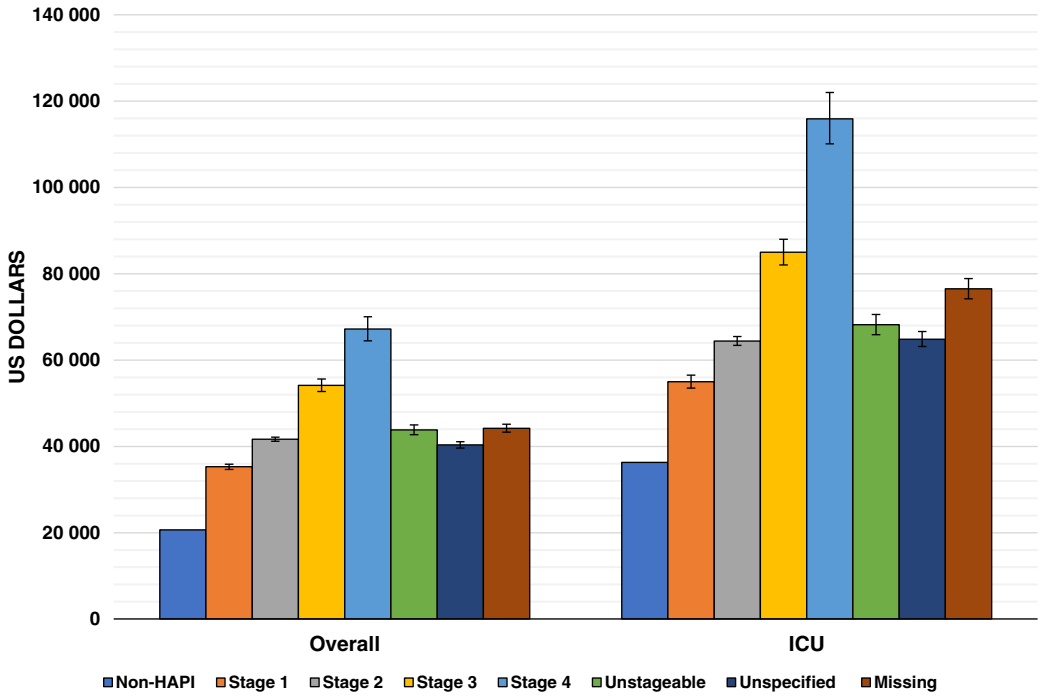

FIGURE 1 Adjusted mean total costs overall and among patients with an ICU stay. Generalised linear models with a gamma distribution and log link were used, and adjusted for propensity score, provider area (midwest, west, south, northeast), and discharge status (expired; home; SNF, Rehab, ICF or long term care; transferred to acute care; other). In-hospital mortality is included as part of the discharge status variable ("expired"), so was not included separately as an adjustment variable. Error bars are 95% confidence intervals. Error bars are not displayed for the non-HAPI group, as they are extremely small

generally higher in the ICU, the impact of HAPI on mortality in the ICU may be obscured in this setting. In a study of 684 patients with a pressure injury present on admission or who developed a pressure injury during hospitalisation, Khor et al[5] found that 66% expired by the end of a 14-week follow-up period. However, it should be noted that these patients had an average age of 80.8 years. Manzano et al,[20] in a study of 563 ICU patients on mechanical ventilation (19.5% of whom developed HAPI), 48.7% of these patients expired during their hospitalisation. In the current study, the overall unadjusted in-hospital mortality rate was 13.1%, with 21.7% of patients with Stage 4 HAPI expiring during the index hospitalisation. There are several possible reasons for the lower unadjusted percentages of mortality in the current study, including no follow-up, and that patients in the current study did not all have ICU stays or mechanical ventilation.

Hospitalisation costs increased as a function of HAPI stage, with total adjusted costs reaching $67 198 (2014 US dollars) for Stage 4 HAPIs compared with $20 684 for patients with no HAPI, thereby representing an incremental cost of $46 514 for Stage 4 HAPI. The incremental cost increased as a function of HAPI stage. The incremental cost of a pressure injury, based on the weighted average across all stages, was $21 767. Of note, this cost estimate is higher than our previous estimate of $8014 and the approximately $10 000 from Padula et al.[12] The goals of our previous work were to examine risk factors and healthcare utilisation for HAPI overall and not by severity. Therefore, the previous study utilised a different study design, excluded patients at the extremes of care, such as those who expired during the index visit, those with LOS greater than 30 days, and those with costs greater than the 99th percentile ($87 000), and included a smaller sample of patients. The goal of the current study was to examine a more complete economic assessment of HAPIs by accounting for staging information and including patients at the extremes of care, which represents a significant burden for HAPI patients.

Using the average incremental cost estimates from our current study ($21 767), and assuming 10 000 annual admissions with a 3.6% HAPI incidence rate, the annual incremental cost to a hospital would be $7.8 million for HAPIs. This translates to $27.3 billion in annual national costs, assuming 35 million annual admissions and a national HAPI incidence rate of 3.6%.[4] (This assumes the ratio between HAPI stages approximately follows the results from the current study.) This estimate is consistent with recent estimates from Padula et al[12] of $26.8 billion (2016 US dollars) for the annual national costs for HAPIs. The Padula et al study estimated the average

TABLE 4 Incremental adjusted costs overall and among patients with an ICU stay

HAPI Classification	Number of Patients in Sample (N)[a]	Incremental Cost (USD)[b]	Weighting Factor[c]	Weighted Contribution to the Total (USD)[d]
Overall				
Stage				
1	6931	14 589	0.1641	2394
2	17 172	20 980	0.4066	8531
3	2905	33 467	0.0688	2302
4	1207	46 514	0.0286	1329
Unstageable	3106	23 137	0.0735	1702
Unspecified	6204	19 645	0.1469	2886
Missing	4705	23 533	0.1114	2622
Total	42 230	–	–	21 767
ICU				
Stage				
1	2937	18 676	0.1338	2498
2	8957	28 093	0.4080	11 460
3	1900	48 650	0.0866	4210
4	849	79 577	0.0387	3077
Unstageable	1884	31 880	0.0858	2735
Unspecified	3064	28 531	0.1395	3981
Missing	2367	40 186	0.1078	4332
Total	21 958	–	–	32 292

[a]Only included patients that had non-missing propensity score data.
[b]Difference in total cost of care between patients with and without HAPI; overall average cost of care for patients without HAPI was $20 684; overall average cost of care for patients with ICU stay was $36 317.
[c]N at each stage divided by total number of HAPIs in sample.
[d]Reflects both the incremental cost by stage and frequency of occurrence by stage.

incremental total cost of a HAPI at just $10 000, but this is based on a widely cited yet unconfirmed number of HAPIs treated in hospital or acute care settings each year.

The high cost and resource burden associated with HAPIs is well-documented.[2-4,6,7,13] In addition to confirming the high cost associated with HAPIs, the current study has also shown that HAPIs are strongly associated with other hospital-acquired conditions, which contributes to the overall increased cost and resource burden. It is also important to note that our model only considered measurable costs of care and did not consider economic impact of fines, litigation, or reimbursement penalties, which can be substantial.

After the implementation of CMS penalties in 2008, reported rates of HAPIs decreased quickly. However, it has been speculated that hospitals may be underreporting or incorrectly reporting HAPIs in order to avoid CMS penalties.[14] For example, HAPIs or other hospital-acquired conditions can be incorrectly listed as "present-on-admission", requiring that physician documentation be present to trigger the reporting of a HAPI or hospital-acquired conditions, or excluding certain patients, e.g. those presenting for surgery, or patients with quadriplegia/hemiplegia.[4,14] HAPIs are also subject to surveillance bias, e.g. reduced checking will lead to a reduced number of HAPIs detected.[4,14] In hospitals where additional surveillance for deep vein thrombosis has taken place, the additional surveillance has led to increased detection and poorer quality scores[21] and the authors raise concerns about this, a scenario which could also easily apply to HAPIs. A high rate of coding inconsistencies was found between HAPIs present on admission and new HAPIs in a study of acute inpatient hospital admissions among Medicare fee-for-service beneficiaries in 2011.[22] Additionally, using claims data, Squirtieri et al[23] found a very poor rate of agreement on the presence of HAPIs (kappa = 0.03) and HAPI staging (kappa = 0.17) when transferring patients between facilities and hospitals, which could also be a source of

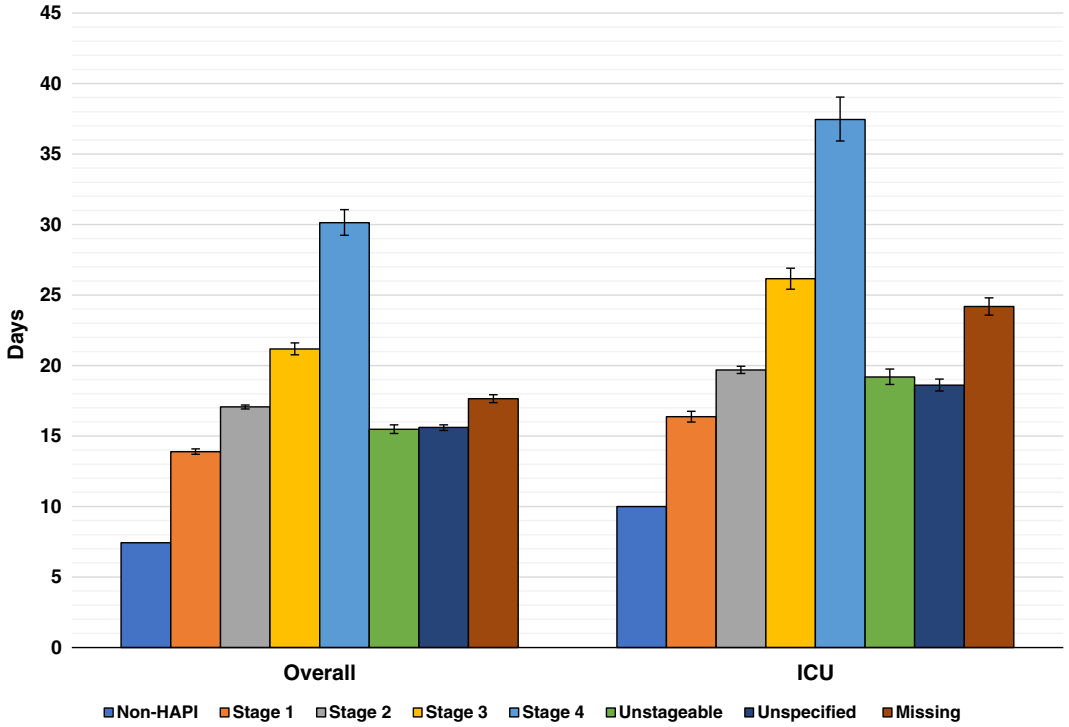

FIGURE 2 Adjusted mean LOS overall and among patients with an ICU stay. Adjusted for propensity score, provider area (midwest, west, south, northeast), and discharge status (expired; home; SNF, Rehab, ICF or long term care; transferred to acute care; other). In-hospital mortality is included as part of the discharge status variable ("expired"), so was not included separately as an adjustment variable. Error bars are 95% confidence intervals. Error bars are not displayed for the non-HAPI group, as they are extremely small

inconsistent or incorrect HAPI reporting. Hospitals may also encompass HAPIs within composite scores or by staging a HAPI as unspecified or unstageable to downgrade the severity.[14] The differences in the incidence of HAPI (0.47%) in the PHD vs the Joint Commission incidence (3.6%) over the same period of time could be partially accounted for by these issues.

There are several strengths and limitations to consider in the current study. The study is exceptionally large, with approximately 9.6 million patients, of which more than 46 000 had a HAPI. HAPIs by stage were assessed, and their associations with mortality and other hospital-acquired conditions were examined, in addition to costs and healthcare resource utilisation outcomes. Adjustment for a number of known HAPI risk factors and potential confounders was accomplished through propensity scores. The study was limited by the reliance on ICD-9 codes to define HAPIs; use of surveillance data may result in somewhat different incidence of HAPIs.[7] As discussed above, there can be inconsistencies when recording HAPIs as present on admission vs incident HAPIs at the current hospitalisation. Although the PHD is not a random sample, during the years of this study (2008-14) it contained approximately 1 in 5 hospital discharges in the US. Relative risks and percentages of admissions may be an underestimate, as patients cannot be tracked between hospitals or providers; nonetheless, HAPI stages were significantly associated with readmissions, and fewer readmissions cases would likely bias the estimates towards the null.

The current study has confirmed the significant cost and resource burden associated with HAPIs, with costs rising predictably as a function of the HAPI stage. The average incremental cost associated with a HAPI was found to be $21 767, which is higher than previous estimates. This study also demonstrated a strong association between HAPIs and several other hospital-acquired conditions, such as VAP, UTI, and VTE. In addition, the study found a strong association between HAPI and in-hospital mortality and risk of readmission at 30, 60, and 90 days. Hospitals should be encouraged to maintain compliance with National Pressure Injury Advisory Panel (NPIAP) guidelines. Awareness of the clinical and financial burden of HAPIs should be increased, through education and dissemination of guidelines. Hospitals can be encouraged to consistently and correctly report HAPIs through policy changes, and standardisation of how HAPIs are reported by removing them from composite scores, discouraging the exclusion of certain patients, e.g. those with quadriplegia, and encouraging electronic medical record-based reporting. Using the many available strategies for preventing HAPIs, as well as potentially

newer algorithms to predict HAPI,[10,24] hospitals should be able to reduce HAPI incidence and reduce costs.

CONFLICT OF INTEREST

CLW was employed by Premier, Inc during work for this manuscript. GD was employed by Smith and Nephew during work for this manuscript and owns Smith and Nephew stock. JAG is employed by Premier, Inc and owns Premier stock. JD was employed by Premier, Inc during work on this manuscript and owns Premier stock. BL is employed by Smith and Nephew.

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SUPPORTING INFORMATION

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

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