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Increases in Mortality, Length of Stay, and Cost Associated With Hospital-Acquired Infections in Trauma Patients

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Objective: To explore the clinical impact and economic burden of hospital-acquired infections (HAIs) in trauma patients using a nationally representative database.

Design: Retrospective study.

Setting: The Healthcare Cost and Utilization Project Nationwide Inpatient Sample.

Patients: Trauma patients.

Main Outcome Measures: We examined the association between HAIs (sepsis, pneumonia, *Staphylococcus* infections, and *Clostridium difficile*–associated disease) and in-hospital mortality, length of stay, and inpatient costs using logistic regression and generalized linear models.

Results: After controlling for patient demographics, mechanism of injury, injury type, injury severity, and comorbidities, we found that mortality, cost, and length of stay were significantly higher in patients with HAIs compared with patients without HAIs. Patients with sepsis had a nearly 6-fold higher odds of death compared with patients without an HAI (odds ratio, 5.78; 95% confidence interval, 5.03-6.64; $P<.001$). Patients with other HAIs had a 1.5- to1.9-fold higher odds of mortality compared with controls ($P<.005$). Patients with HAIs had costs that were approximately 2- to 2.5-fold higher compared with patients without HAIs ($P<.001$). The median length of stay was approximately 2-fold higher in patients with HAIs compared with patients without HAIs ($P<.001$).

Conclusions: Trauma patients with HAIs are at increased risk for mortality, have longer lengths of stay, and incur higher inpatient costs. In light of the preventability of many HAIs and the magnitude of the clinical and economic burden associated with HAIs, policies aiming to decrease the incidence of HAIs may have a potentially large impact on outcomes in injured patients.

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THE INSTITUTE OF MEDICINE has focused attention on preventing medical errors and improving patient safety.[1] Hospital-acquired infections (HAIs) are the most common complication in hospitalized patients,[2] with an estimated incidence of 4.5 HAIs per 100 hospital admissions and an annual cost between $35 billion and $45 billion.[3] Hospital-acquired infections result in more than 90 000 deaths each year,[4,5] ranking death due to HAIs among the top 5 leading causes of death in the United States.[6]

See Invited Critique at end of article

Trauma patients are at especially high risk for the development of infections[7] because of disruptions in tissue integrity and impaired host defense mechanisms.[8,9] Trauma remains one of the main causes of mortality worldwide[10] and is responsible for nearly one-third of "all lost years of productive life before age 65, exceeding losses from heart disease, cancer, and stroke combined."[11] Infections are a leading cause of death in trauma patients.[8] However, to our knowledge, the clinical and economic outcomes of HAIs in trauma patients have not been previously reported using a large nationally representative patient sample.

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In light of the preventability of many HAIs, obtaining a better understanding of the clinical impact of HAI on outcomes in trauma patients may provide the impetus for the implementation of best practices for infection control in injured patients. Recent evidence suggests significant variability in outcomes across trauma cen-

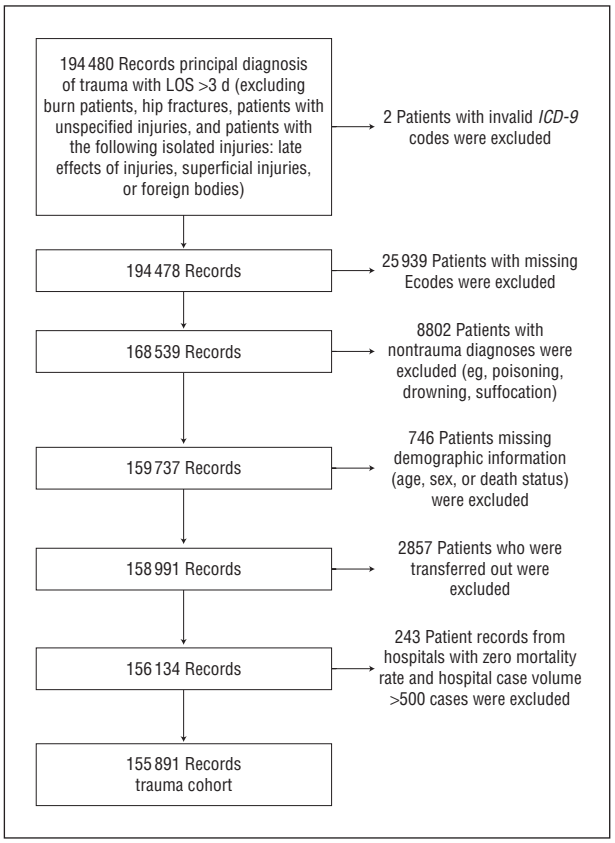

Figure 1. Study population. Ecodes indicates External Cause-of-Injury Coding; *ICD-9, International Classification of Diseases, Ninth Revision;* LOS, length of stay.

ters: trauma patients admitted to the highest-mortality hospitals had a 70% higher odds of dying compared with patients admitted to average hospitals.[12] Some of these differences in outcomes across hospitals may result from differences in hospital HAI rates. A better understanding of the economic cost of HAI in injured patients may also create a strong business case for reducing the incidence of HAIs in this patient population.

The goal of this study was to explore the clinical impact and economic burden of HAIs in trauma patients using a nationally representative database. The analysis will focus on in-hospital mortality, hospital length of stay (LOS), and hospital cost. We selected HAIs associated with sepsis, pneumonia, *Staphylococcus* infections, and *Clostridium* infections because these conditions can be identified using administrative data.[13-16] We assumed that infections in patients admitted with traumatic injuries were likely to be HAIs because infection, or illness related to infection, was not the reason for admission of injured patients.

METHODS

DATA SOURCE

This study was based on data from the 2005 and 2006 Nationwide Inpatient Sample developed by the Healthcare Cost and Utilization Project. The Nationwide Inpatient Sample is the largest all-payer hospital inpatient database in the United States and includes data from a 20% stratified sample of US hospitals. The discharge data contain information on patient demographics, admission source, *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) diagnostic and injury codes, Agency for Healthcare Research and Quality comorbidity measures,[17] charges, LOS, in-hospital mortality, hospital characteristics, and hospital identifiers. Hospital trauma center status was obtained from the American Hospital Association Annual Survey. Hospital costs were calculated by multiplying the total hospital charges by the group average cost to charges ratios (defined as a weighed average for the hospitals in a group based on state, urban/rural, hospital ownership, and hospital size).[18]

Table 1. Criteria for Identifying Health Care–Associated Infections

Infection Type	*ICD-9-CM* Discharge Diagnosis Codes
Sepsis	038-038.9, 112.5, 112.81, 785.52, 995.91, and 995.92
Pneumonia	482.0-482.2 and 482.4-482.9
Staphylococcus	730.0-730.09, 711-711.09, 038.11, 041.11, 482.41, V09.0, V09.8, 008.41, 038.1, 790.7, 996.62, 421.0, 996.61, 998.3, and 998.5
Clostridium difficile	008.45

Abbreviation: *ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification.*

STUDY POPULATION

The study population consisted of patients admitted with a principal *ICD-9-CM* diagnosis of trauma (codes 800-959.9) and LOS more than 3 days, after excluding patients with burns (*ICD-9-CM* codes 940-949); unspecified injuries (*ICD-9-CM* codes 959-959.9); and hip fractures (*ICD-9-CM* codes 820-820.9) and patients with the following isolated injuries: late effects of injury (*ICD-9-CM* codes 905-909.9), superficial injuries (*ICD-9-CM* codes 910-924.9), or foreign bodies (*ICD-9-CM* codes 930-939.0). Patients with LOS less than 3 days were excluded because we assumed that patients who were either discharged or died within 3 days would not have time to have developed HAIs. From this initial cohort of 190 480 patient records, we excluded 25 939 patients with missing External Cause-of-Injury Coding (Ecodes), 8802 patients with nontraumatic mechanisms (eg, poisoning, drowning, suffocation), 746 patients missing demographic information (age, sex, or death status), 2857 patients who were transferred out, and 243 patient records from hospitals with a hospital case volume greater than 500 cases with zero mortality rates. The final study cohort consisted of 155 891 patient records (**Figure 1**).

DEFINITIONS

For the purpose of this analysis, 4 different HAI groups were defined using *ICD-9-CM* codes: (1) sepsis, (2) pneumonia, (3) *Staphylococcus* infections, and (4) *Clostridium difficile*–associated disease (CDAD). The criteria used for identifying HAIs are shown in **Table 1**. Individual patients could have more than 1 HAI. The criteria used to identify cases with sepsis and pneumonia have been previously validated[13,19] and used by other investigators.[14] Criteria used to identify *Staphylococcus* infections and CDAD are based on previously published algorithms.[15,16] We assumed that all cases identified using these algorithms represented HAIs since it is unlikely that patients admitted with traumatic injuries would have preexisting infections.

STATISTICAL ANALYSIS

The outcome variables of interest were mortality, LOS, and hospital cost. Separate patient-level analyses were conducted to examine the association between each of the outcome variables and the presence of either sepsis, pneumonia, *Staphylococcus* infection, or CDAD.

In the first set of analyses, we explored the association between mortality and sepsis, after controlling for patient demographics (age and sex), mechanisms of injury, injury severity, and comorbidities using logistic regression. Patient comorbidities were coded using the Agency for Healthcare Research and Quality Comorbidity Algorithm.[17] Injury severity was coded using empirically derived estimates of injury severity based on the previously validated Trauma Mortality Probability Model.[12,20] Backward stepwise selection and clinical judgment were used to select comorbidity variables for inclusion in the regression model. Robust variance estimators were used to account for the nonindependence of observations within hospitals. The effect of sepsis on mortality was assessed using the adjusted odds ratio (AOR). We repeated these analyses using either pneumonia, *Staphylococcus* infection, or CDAD as the exposure variable. In each of the analyses, the reference category only included patients without any of the HAIs (as defined earlier).

In the second set of analyses, we explored the association between cost and sepsis, after controlling for patient demographics (age and sex), mechanisms of injury, injury, comorbidities, and hospital factors (teaching status, rurality, geographic region). The *ICD-9-CM* injury diagnoses were coded as binary indicator variables. We used a generalized linear model[21] with a log link function and a gamma variance function. The variance function was selected using an approach previously described by Manning and Mullahy.[22] Robust variance estimators were used because patient outcomes in the same hospital may be correlated.[23] The adjusted ratio of hospital cost for patients with sepsis compared with patients without an HAI was assessed by exponentiating the estimated model parameter for cost (eAppendix, http://www.archsurg.com). We repeated these analyses using either pneumonia, *Staphylococcus* infection, or CDAD as the exposure variable. In the third set of analyses, we separately explored the association between LOS and each of the HAI categories. The models were specified using the same functional form as the cost models.

In the final analysis, we estimated a prediction model for composite measure of HAI (sepsis, pneumonia, *Staphylococcus*, or CDAD) as a function of patient demographics (age and sex), mechanisms of injury, injury severity, body region, and comorbidities. Backward stepwise selection was used to select comorbidity variables for inclusion in the regression model. Robust variance estimators were used to account for the nonindependence of observations within hospitals.

All statistical analyses were performed using Stata SE/MP version 11.0 (StataCorp, College Station, Texas). The performance of the logistic regression models (for mortality) was assessed using measures of discrimination (C-statistic) and calibration (the Hosmer-Lemeshow statistic).

RESULTS

Table 2 displays information on hospital demographics. Sixty-two percent of the hospitals were located in urban areas and 80% of the hospitals were nonteaching institutions. The hospitals were distributed across all 4 major geographic regions.

Table 3 summarizes patient demographics and comorbidities. Patients with pneumonia and *Staphylococcus* infections were more likely to be younger than control patients, whereas patients with CDAD were older than control patients. Compared with controls, patients with sepsis, pneumonia, and *Staphylococcus* infections were less likely to be female. Across all patient groups, the most common mechanism of injury was blunt trauma. However, patients with pneumonia were more likely to be in a motor vehicle accident compared with controls (35.2% vs 18.4%) and also more likely to sustain pedestrian trauma (15.6% vs 7.4%). The incidence of congestive heart failure was higher in patients with sepsis and CDAD compared with patients without HAIs. Patients with sepsis and CDAD were also more likely to have renal failure compared with controls. A higher percentage of patients with CDAD had chronic pulmonary disease compared with controls.

Patients with HAIs were less likely to be female (AOR, 0.70; 95% CI, 0.66-0.75). Patients whose mechanism of injury was either a motor vehicle accident (AOR, 1.25; 95% confidence interval [CI], 1.15-1.36; *P* value <.001), gunshot wound (AOR, 1.28; 95% CI, 1.12-1.45; *P* value <.001), stab wound (AOR, 1.74; 95% CI, 1.48-2.06; *P* value <.001), or pedestrian trauma (AOR, 1.49; 95% CI, 1.34-1.64; *P* value <.001) were more likely to develop an HAI compared with blunt trauma patients (**Table 4**). Patients with injuries to the head (AOR, 1.32; 95% CI, 1.21-1.43; *P* value <.001) or chest region (AOR, 1.22; 95% CI, 1.14-1.30; *P* value <.001) had a higher risk of HAI, whereas injuries to the extremities (AOR, 0.80; 95% CI, 0.74-0.87; *P* value <.001) were associated with a lower risk of HAI, compared with abdominal injuries.

Table 2. Hospital Demographics[a]

Demographic	No. (%)
Location	
Rural	586 (38.1)
Urban	951 (61.8)
Hospital size	
Small	612 (39.8)
Medium	417 (27.1)
Large	508 (33.0)
Teaching status	
Teaching	301 (19.6)
Nonteaching	1236 (80.3)
Trauma center accreditation[b]	
Level I	95 (6.2)
Level II	113 (7.3)
Level III	150 (9.8)
None	650 (42.2)
Missing	530 (34.4)
Geographic region	
Northeast	215 (14.0)
South	604 (39.3)
Midwest	424 (20.7)
West	296 (19.2)

[a] Hospital demographics for study sample. The bed size corresponding to small, medium, and large varies depending on the geographic region, rural vs urban, and teaching status. The number of hospitals within each category does not add up to 1539 because of missing data on hospital demographics.

[b] Thirty-four percent of the hospitals in the Nationwide Inpatient Sample were missing American Hospital Association AHAID identifiers and could not be linked to the American Hospital Association database to determine trauma center designation status.

Table 3. Characteristics of Patients With HAIs

	%					
	Control	HAI	Sepsis	Pneumonia	*Staphylococcus*	*Clostridium difficile*
No. (%) of patients[a]	148 880	7011 (4.50)	2955 (1.90)	2479 (1.59)	3803 (2.44)	768 (0.49)
Age, y, median (IQR)	57 (34-78)	53 (32-74)	58 (38-77)	47 (27-66)	49 (31-71)	69 (45-82)
Female	48.0	33.4	33.8	24.6	32.3	47.7
Injury mechanism						
Blunt trauma	48.5	43.5	44.8	36.0	43.9	51.2
Motor vehicle accident	18.4	24.0	22.2	35.2	22.7	17.4
Gunshot wound	3.6	4.8	5.6	5.0	4.6	2.5
Stab wound	3.1	4.1	1.7	1.3	6.0	1.8
Pedestrian trauma	7.4	11.1	11.3	15.6	11.0	6.10
Low fall	19.0	14.5	14.5	7.1	11.8	21.0
Body region[b]						
Head	27.1	51.1	50.7	72.9	49.0	40.9
Face	7.1	9.3	7.9	14.0	9.1	6.4
Chest	23.7	36.1	36.7	50.9	33.2	27.8
Abdomen	18.7	23.0	26.3	24.8	19.9	20.8
Extremity	58.4	39.0	38.1	30.6	39.2	43.3
Superficial	14.2	14.6	8.6	14.0	18.5	9.6
Comorbidities						
Congestive heart failure	7.6	11.7	15.6	8.0	9.4	18.2
Valvular disease	4.0	3.6	4.7	2.4	2.8	5.7
Pulmonary circulation disorders	0.67	0.68	0.78	0.48	0.50	1.43
Peripheral vascular disease	2.6	3.1	2.9	1.9	3.0	5.1
Hypertension	36.2	27.6	27.6	20.7	27.2	39.0
Renal failure	4.1	7.1	9.6	3.6	5.9	11.8
Liver disease	1.4	2.8	3.6	2.2	3.0	1.4
Paralysis	2.5	4.9	4.4	6.0	5.3	5.1
Other neurologic disorder	6.3	8.5	8.7	9.8	8.3	9.5
Chronic pulmonary disease	12.5	14.0	13.8	12.7	13.0	19.1
Diabetes	12.4	9.6	10.1	7.4	9.8	11.6
Diabetes, chronic complications	2.5	3.0	3.0	1.1	3.8	5.8
Hypothyroidism	7.7	4.1	3.8	2.5	3.8	7.4
Lymphoma	0.33	0.43	0.64	0.20	0.42	0.52
Metastatic cancer	0.55	0.56	0.78	0.28	0.60	0.91
Solid tumor without metastasis	0.82	0.94	0.91	0.32	0.74	2.60
Rheumatoid arthritis	1.9	1.2	1.1	0.89	1.2	1.3
Coagulation deficiency	2.7	8.3	11.1	8.6	6.8	6.8
Obesity	3.8	2.7	2.3	1.7	2.8	3.6
Weight loss	1.8	10.3	11.7	14.2	8.5	11.2
Fluid and electrolyte disorder	14.5	33.3	38.3	37.6	29.8	37.3
Blood loss anemia	1.5	2.6	2.5	3.2	2.3	3.5
Deficiency anemia	10.9	12.9	12.8	11.9	13.1	18.1
Peptic ulcer disease	0.03	0.01	0	0.04	0	0
Alcohol abuse	9.1	13.1	12.7	16.8	13.6	9.9
Drug abuse	4.3	5.6	5.2	6.0	6.4	3.3
Psychoses	3.4	3.2	2.9	2.5	3.6	3.6
Depression	7.1	4.9	4.3	3.3	5.4	8.3

Abbreviations: HAI, hospital-acquired infection; IQR, interquartile range.
[a] Groups are not mutually exclusive (eg, patients in the sepsis group could also have a *Staphylococcus* infection).
[b] Groups are not mutually exclusive. Patients could have injuries in more than 1 body region.

Crude mortality rates, costs, and LOS were all much higher in patients with HAIs compared with patients without HAIs (**Table 5**). The overall mortality rate for control patients was 1.99%, compared with 21.2% for patients with sepsis, 10.6% for patients with pneumonia, 7.91% for patients with *Staphylococcus* infections, and 7.27% for patients with CDAD. Compared with other injury mechanisms, low-fall patients with HAIs experienced the highest mortality.

Total inpatient costs were between 2.6 to 6 times higher in patients with HAI compared with patients without HAIs (Table 5). Patients with sepsis ($60 398) and pneumonia ($77 393) had the highest median costs compared with control patients ($12 849). Inpatients with HAI had nearly a 3- to 4-fold higher LOS compared with patients without HAIs.

After controlling for patient demographics, mechanism of injury, injury type, and comorbidities, we found that mortality, cost, and LOS were significantly higher in patients with HAIs compared with patients without HAIs (**Figures 2**, **3**, and **4**). Patients with sepsis had a nearly 6-fold higher odds of death compared with pa-

Table 4. Results of Multivariate Model for Development of Hospital-Acquired Infection

	AOR (95% CI)	*P* Value
Age[a]	1.02 (1.01-1.04)	.001
Female	0.70 (0.66-0.75)	<.001
Injury mechanism		
Blunt trauma	1 [Reference]	
Motor vehicle accident	1.25 (1.15-1.36)	<.001
Gunshot wound	1.28 (1.12-1.45)	<.001
Stab wound	1.74 (1.48-2.06)	<.001
Pedestrian trauma	1.49 (1.34-1.64)	<.001
Low fall	0.90 (0.82-0.98)	.01
Body region		
Head	1.32 (1.21-1.43)	<.001
Face	1.07 (0.99-1.16)	.10
Chest	1.22 (1.14-1.30)	<.001
Abdomen	1 [Reference]	
Extremity	0.80 (0.74-0.87)	<.001
Superficial	1.00 (0.91-1.09)	.94
Comorbidities		
Congestive heart failure	1.63 (1.48-1.79)	<.001
Hypertension	0.74 (0.69-0.80)	<.001
Renal failure	1.70 (1.50-1.92)	<.001
Liver disease	1.43 (1.21-1.68)	<.001
Paralysis	1.46 (1.27-1.67)	<.001
Other neurologic disorder	1.55 (1.41-1.71)	<.001
Chronic pulmonary disease	1.28 (1.18-1.38)	<.001
Diabetes, chronic complications	1.57 (1.35-1.82)	<.001
Hypothyroidism	0.70 (0.61-0.81)	<.001
Coagulation deficiency	1.73 (1.54-1.93)	<.001
Weight loss	3.09 (2.66-3.59)	<.001
Fluid and electrolyte disorder	2.22 (2.05-2.39)	<.001
Blood loss anemia	1.37 (1.08-1.74)	.009
Deficiency anemia	1.16 (1.06-1.27)	.002
Depression	0.89 (0.80-0.99)	.03

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval.
[a] Age is in increments of 10 years.

tients without an HAI (OR, 5.78; 95% CI, 5.03-6.64; $P<.001$). Patients with other HAIs had a 1.5- to 1.9-fold higher odds of mortality compared with controls ($P<.005$). Patients with HAIs had costs that were 2- to 2.5-fold higher compared with patients without HAIs ($P<.001$). The median LOS was approximately 2-fold higher in patients with HAIs compared with patients without HAIs ($P<.001$).

The logistic regression models exhibited excellent discrimination. The C-statistics for the mortality models ranged between 0.88 and 0.90; the C-statistic for the model predicting HAIs was 0.76. Model calibration, assessed using the Hosmer-Lemeshow statistic, ranged between 31 and 186 and is acceptable given the Hosmer-Lemeshow statistic's well-known sensitivity to sample size and the very large size of our patient cohort.[24]

COMMENT

In this study based on the Healthcare Cost and Utilization Project Nationwide Inpatient Sample, we found that trauma patients with HAIs are at increased risk for mortality, have longer LOS, and incur higher inpatient costs. In particular, trauma patients with sepsis had a 6-fold higher risk of mortality, whereas patients with other HAIs had a nearly 1.5- to 2-fold higher mortality compared with patients without an HAI. Furthermore, patients with HAIs had LOS and inpatient costs that were approximately 2-fold higher than patients without HAIs.

Reducing HAIs is one of the top priorities in the efforts by the federal government and nongovernmental entities to improve patient safety and health care outcomes in the United States. In particular, the US Department of Health and Human Services has established a national agenda for HAI prevention in an Action Plan that outlines a strategy to reduce the incidence of HAIs by 75% over a 5-year period.[25] Furthermore, in this action plan, methicillin-resistant *Staphylococcus aureus* and CDAD acquired in the acute hospital setting have been identified as priority areas. The National Quality Forum has identified the prevention of health care–associated infections as a key area for improving patient safety in its list of *Safe Practices for Better Healthcare*.[26] Three of the 6 recommended practices in the Institute for Healthcare Improvement's 100 000 Lives Campaign are focused on the prevention of HAIs.[27] Mandatory public reporting of hospital HAI rates is becoming more widespread as part of the effort to increase transparency and accountability to achieve reductions in HAIs.[28-30] Finally, the Centers for Medicare and Medicaid Services is no longer reimbursing hospitals for some HAIs as part of the legislatively mandated initiative to penalize hospitals for hospital-acquired conditions.[31-33]

To our knowledge, our study is the first population-based epidemiologic study of HAIs in trauma patients using a large nationally representative database. Many of the previous studies on trauma patients with HAIs have focused on identifying risk factors for the development of HAIs.[9,34-42] Other studies have described the epidemiologic features of HAI in the trauma patients[7,43-48] Our findings confirm the findings of previous studies that HAIs in trauma patients are associated with increased mortality,[36] LOS,[8,36,47] and cost.[8,47] In 2 of these previous studies, researchers did not find an independent association between HAI and mortality.[45,47] All of these prior studies were relatively small and all were single-center studies, limiting the generalizability of their findings.

There are several important limitations to our study. First, administrative data are not as accurate as clinical records and do not capture all instances of HAIs. However, the accuracy of administrative data for identifying cases of sepsis has been validated in a previous epidemiologic study.[13] For pneumonias, *ICD-9-CM* codes demonstrate high specificity for the detection of pneumonias, but the sensitivity is approximately 50%. The accuracy of *ICD-9-CM* codes for detecting cases of *Staphylococcus* infections and CDAD is largely unknown.[15,16] The undercoding of other hospital-acquired complications using administrative data has been confirmed in validation studies of the Agency for Healthcare Research and Quality Patient Safety Indicators.[49] The undercoding of HAIs may be a source of bias in our analysis and may lead us to underestimate the impact of HAIs on outcomes if a significant number of patients with HAIs are included in the reference population of patients without HAIs.

Second, the use of the Trauma Mortality Probability Model may not have completely adjusted for disease se-

Table 5. Mortality, Cost, and Length of Stay of Patients With Hospital-Acquired Infections

	Control	Sepsis	Pneumonia	*Staphylococcus*	*Clostridium difficile*
No. (%) of patients	148 888	2955 (1.59)	2479 (1.59)	3803 (2.44)	768 (0.49)
Mortality, %					
Overall	1.99	21.2	10.6	7.91	7.27
Blunt trauma	2.09	23.0	12.4	9.10	8.38
Motor vehicle accident	2.03	17.1	7.34	6.36	0.75
Gunshot wound	1.99	15.7	10.6	6.86	5.26
Stab wound	0.50	8.0	3.23	0.44	7.14
Pedestrian trauma	1.82	18.3	9.84	6.71	6.38
Low fall	1.99	30.3	19.9	11.8	10.5
Cost, $, median					
Overall	12 849	60 398	77 393	47 908	33 294
Blunt trauma	11 515	45 046	70 551	33 759	26 225
Motor vehicle accident	17 729	86 290	82 997	74 830	65 754
Gunshot wound	18 213	93 770	87 045	73 677	47 489
Stab wound	12 111	49 767	61 641	10 196	27 984
Pedestrian trauma	19 384	99 037	86 025	79 597	90 691
Low fall	10 270	36 229	55 945	24 670	21 276
Length of stay, d, median					
Overall	6	20	24	17	16
Blunt trauma	6	17	23	15	14
Motor vehicle accident	6	25	25	23	22
Gunshot wound	7	29	26	24	17
Stab wound	5	20	22	7	12
Pedestrian trauma	7	29	27	25	30
Low fall	5	15	30	13	13

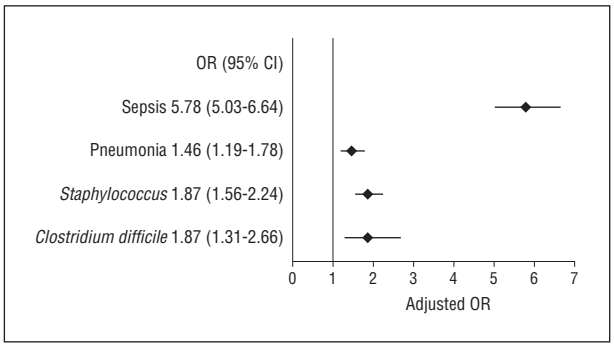

Figure 2. Impact on mortality of hospital-acquired infections controlling for patient demographics, mechanism of injury, injury severity, and comorbidities. CI indicates confidence interval; OR, odds ratio.

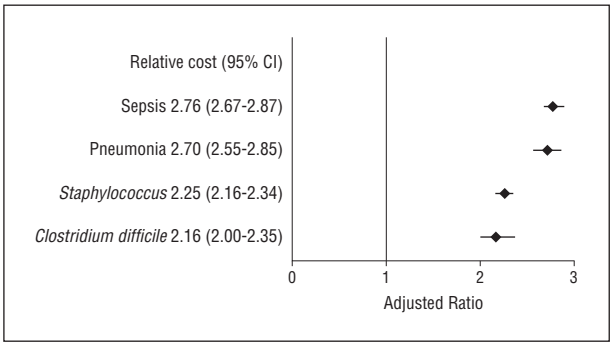

Figure 3. Impact on inpatient costs of hospital-acquired infections controlling for patient demographics, mechanism of injury, injury, comorbidities, and hospital factors (teaching status, rurality, geographic region). CI indicates confidence interval.

verity because of the lack of information on patient physiology in administrative data.[20] The Trauma Mortality Probability Model–*ICD-9* is based on *ICD-9-CM* injury codes but does not include important information on patient physiology such as Glasgow Coma Scale scores and vital signs on hospital admission. However, the statistical performance of the Trauma Mortality Probability Model–*ICD-9* is excellent, minimizing the potential for omitted variable bias.[20] Third, we were unable to explore the impact of HAIs on other important quality domains such as functional outcomes because these outcome data are not included in administrative data. Future work exploring the impact of HAIs on other quality domains will be necessary once these additional outcomes data become available.

Third, the Nationwide Inpatient Sample does not allow us to determine whether infections identified as HAIs were present on admission or developed as a complication of the hospital stay. Therefore, it is possible that some of the infections represent community-acquired infections as opposed to HAIs. However, it is likely that most infections in trauma patients are hospital acquired. Although this is a reasonable assumption for trauma patients, we were not able to verify this assumption because of the absence of a present-on-admission indicator in the Nationwide Inpatient Sample. Despite these limitations, to our knowledge, this study is the first analysis of the impact of HAIs in trauma patients using a large nationally representative database. Although it shares many of the same limitations of other epidemiological investigations conducted using large administrative data sets, it has the advantage of a large sample size not possible in studies based on prospectively collected clinical data.

Finally, our estimate of the association between HAIs and LOS may overestimate the effect of HAI on LOS. A

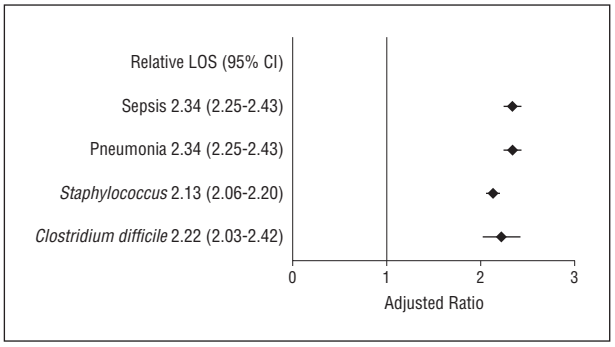

Figure 4. Impact on length of stay (LOS) of hospital-acquired infections controlling for patient demographics, mechanism of injury, injury, comorbidities, and hospital factors (teaching status, rurality, geographic region). CI indicates confidence interval.

priori, patients who develop HAIs would be expected to have longer LOS. However, patients who stay longer in the hospital would also be expected to be at higher risk of developing HAIs. As a result, the estimated correlation may overstate the influence of HAI on LOS. Statistical techniques to deal with this problem of endogeneity between LOS and HAIs, ie, the use of instrumental variables, would not be feasible here. This limitation is partially offset because the LOS model includes many of the important determinants of LOS. This same issue applies to the association between HAIs and cost because the LOS is an important element of cost. The practical impact of this bias from a policy perspective is lessened by the fact that policies designed to reduce the likelihood of HAIs could also include efforts to reduce LOS.

In summary, HAIs are associated with increased mortality, LOS, and inpatient costs in patients admitted with traumatic injuries. In light of the preventability of many hospital-acquired conditions[50,51] and the magnitude of the clinical and economic burden of HAIs, the current emphasis on implementing interventions aiming to decrease the incidence of HAIs may have a potentially large impact. The current shift in payment policies away from "output-based funding" toward "outcomes-based funding" may act as a catalyst for patient safety initiatives designed to reduce HAIs and improve patient outcomes.[32] Future studies will be necessary to assess the impact of recent changes in Centers for Medicare and Medicaid Services payment policies on the incidence of HAIs.

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Online-Only Material: The eAppendix is available at http://www.archsurg.com.

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INVITED CRITIQUE

ONLINE FIRST

Life, Liberty, and the Pursuit of HAIs

In 1776, Thomas Jefferson penned the words "We hold these truths to be self-evident, that all men are created equal, that they are endowed by their Creator with certain unalienable Rights, that among these are Life, Liberty and the pursuit of Happiness." Glance and colleagues pursued HAIs in trauma patients instead, and they, like Jefferson, state the obvious: infections make trauma patients sicker and sicker patients do worse; they die more, they consume more resources, and they stay longer. Or as my teenage son would say, "Duh, Dad, everyone knows that." So why do we need another article that states the obvious? Well, for one, we now put science before assumption, even universally self-evident assumption. Yes, discharge databases are messy; yes, they have flaws; and yes, they are still maturing and require validation, but if we dismiss them, why do we even bother collecting the data? Glance and colleagues show that even discharge databases have something to share with us about improving patient care, and this is one of the largest, a cohort of 155 891 trauma patient records. Even with all the small inherent errors in a database (remember, small error rises exponentially when compounded together), we are still left with the fact that HAIs hurt trauma patients and hurt them a lot. Why? Maybe that standard preoperative antibiotic dose is too small for the expanded volume of distribution in trauma, maybe aspiration is more common than we thought, maybe we use too much immunosuppressing blood in resuscitation, maybe, maybe, maybe. We need to pursue those HAIs, and it doesn't seem to matter if it is in an accredited trauma center or not. In fact, only 23.3% of sample hospitals were identified as such in the article. Working in a level I trauma center, I hope I avoid HAIs better than most, but I may have to wait for Glance and colleagues' next article to know for sure.

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