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ORTHOPAEDIC SURGERY

Occurrence of never events after total joint arthroplasty in the United States

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Abstract

Background Total joint arthroplasty (TJA) is a major orthopedic procedure associated with substantial morbidity and mortality. Never events (NEs) are harmful hospital-acquired conditions (HACs) that are preventable.

Methods Information on hospital admissions with TJA was collected from the National Inpatient Sample (NIS) from 2003 to 2012. NIS was queried to identify NE applicable to TJA patients based on the HAC definition listed by the Centers for Medicare and Medicaid Services (CMS). NEs were further compared before and after 2008 to evaluate the effect of the new CMS non-reimbursement policy on their incidence.

Results A total of 8,176,774 patients were admitted with TJA from 2003 to 2012. 108,668 patients of these (1.33%) had ≥ 1 NE. The most prevalent NE was fall and trauma (0.7%). Significant multivariable predictors with higher odds of developing at least one NE included weekend admission [odds ratio (99.9% CI), 4.3 (3.1, 5.8), $p < 0.001$] and weight loss [odds ratio (99.9% CI), 2.8 (2.2, 3.5), $p < 0.001$]. A temporal comparison of NE before and after 2008 revealed a decrease in total NE occurrence after 2008 when the CMS announced discontinuing payment for NE (1.39% vs. 1.25%, $p < 0.001$). After adjustment for potential confounding risk factors, NE after TJA was significantly associated with an increased mortality ($p < 0.001$), a longer hospital stay ($p < 0.001$), and higher total hospitalization charges ($p < 0.001$).

Conclusions These data demonstrated that NE in TJA patients was predictive of an increased mortality, length of hospital stay, and hospitalization costs. This study established baseline NE rates in the TJA patient population to use as benchmarks and identified target areas for quality improvement in US.

Keywords Never events · Total joint arthroplasty · Hospital-acquired condition · National Inpatient Sample · Total hip arthroplasty · Total knee arthroplasty · Medical quality

Introduction

The Institute of Medicine's "To Err is Human" report in 1999 first placed the spotlight on preventable medical errors in the United States [1]. "Never events" (NEs) refer to the hospital-acquired conditions (HACs) which are deemed to be largely preventable. The term of NE was introduced in 2001 with reference to the apparently shocking medical errors that should never happen in the process of patient care [2]. Adverse events occurring during surgical inpatient hospital admissions such as wrong-site operations, vascular catheter infection, foreign body retention, catheter-based urinary tract infection, complications with poor blood glucose control, and advanced pressure ulceration are considered NE. The list of errors, which are unambiguous and preventable, was formalized in 2002 by the National Quality Forum and expanded in 2011 [3]. The Centers for Medicare and Medicaid Services (CMS) evaluated these inpatient complications in 2008 and decided that the increased charges associated with treatment for these preventable adverse events would no longer be reimbursed in the inpatient settings [4].

Total joint arthroplasty (TJA) including total hip arthroplasty (THA) and total knee arthroplasty (TKA) is one of the most commonly performed and one of the fastest growing major orthopedic procedures in the United States [5, 6]. Each year over 1 million THA and TKA procedures are performed and the number has been increasing as the population in the United States continues to age, with estimates

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of 600% increases in TKA and 200% increases in THA procedures by 2030 [7]. The patients with TJA procedures are at a high risk for morbidity and mortality. Establishment of baseline prevalence and risk factors of NE can help guide patient care policy for this at-risk population. The purpose of the study was to identify the incidence, predictive factors, and associated consequences of NE for patients undergoing TJA. Furthermore, we compared NEs before and after 2008 to evaluate the temporal trend and the effect of the new CMS non-reimbursement policy on their occurrence.

Methods

The study was conducted using the National Inpatient Sample (NIS) in the United States. NIS utilized information of all US hospitals collected in the federal Healthcare Cost and Utilization Project (HCUP) [8]. Hospitals in the NIS were randomly selected to achieve an approximately 20% sample of all US hospitals. NIS is the largest all-payer inpatient care database and provides information of approximately 8 million inpatient stays from over 1000 hospitals [8]. An individual entry within the NIS corresponded to a single inpatient episode. Patient-level sampling weights were included to enable the generation of national estimates. The data from the representative hospitals sampled by the NIS represented a weighted estimate of over 95% of the US population. NIS provided information on primary and secondary diagnoses, demographics, procedures, total charges, source of payment, length of stay, and comorbidity for each inpatient hospitalization. More than 100 variables were collected for each inpatient admission, encompassing patient demographic, comorbidities, outcomes, hospital characteristics, and financial information. All data presented in this study were national estimates based on NIS sampling weights. NIS was queried for all patients undergoing TJA including THA and TKA for this study. Information on hospital admissions of these THA and TKA patients collected from 2003 to 2012 was used for the analyses. All primary and revision THA and TKA procedures within the NIS database were identified with International Classification of Diseases, ninth edition (ICD-9) CM codes.

From the NIS database, we obtained patient's information including preadmission co-morbidities, procedures, patient's demographic data, and characteristics of hospitals, such as patient age, sex, race, ethnicity, income level, hospital bed size, hospital geographic region, academic hospital affiliation, year of surgery, and discharge disposition [8]. Preoperative co-morbidities were extracted using the previously described algorithms by Elixhauser et al. [9]. The HCUP Comorbidity Software was used to generate Elixhauser comorbidities from ICD-9 CM diagnosis codes (https://www.hcup-us.ahrq.gov/toolssoftware/comorbidity/comorbidity.jsp). The Deyo modification of the Charlson Comorbidity Index (CCI) was used to define severity of co-morbid conditions [10]. Surgery type was included as a covariate in the multivariable modeling, grouped into primary TKA, revision TKA, primary THA, and revision THA [6, 7]. Overall hospital costs were estimated from NIS hospital charges data. As direct measurement of hospital costs was impractical across the hospitals sampled by the NIS, HCUP used a formula to convert hospital charges to estimated costs. The data were internally validated for consistency annually. Hospitalization costs included inpatient hospital costs accrued during the index inpatient hospital stay and did not include rehabilitation facility charges, skilled nursing facility, or outpatient treatment for complications which arose during the index hospitalization. As the study period included the years from 2003 to 2012, hospital costs throughout the study period were adjusted for inflation to 2013 US dollars using the gross domestic product deflator (Table 1.1.4 Price Indexes for Gross Domestic Product, U.S. Department of Commerce, Bureau of Economic Analysis. http://www.bea.gov/iTable/iTable.cfm?reqid=9&step=3&isuri=1&903=13#reqid=9&step=3&isuri=1&904=1998&903=4&906=a&905=2013&910=x&911=0). Hospital length of stay was extracted from the database and defined discretely as time from postoperative admission to discharge.

As defined by the final HAC list in the CMS's Nonpayment Program of 2008 [3, 4], NEs applicable to this cohort with THA and TKA procedures were identified using ICD-9 CM diagnosis codes, which included foreign object retained after surgery, air embolism, blood incompatibility, pressure ulcer stages III and IV, falls and trauma, catheter-associated urinary tract infection, vascular catheter-associated infection, manifestations of poor glycemic control, surgical site infection following orthopedic procedures, deep vein thrombosis and pulmonary embolism following orthopedic procedures, and iatrogenic pneumothorax with venous catheterization.

Data are presented as mean ± standard deviation for continuous variables or weighted frequency in percentage for categorical variables. NE prevalence was estimated by calculating the number of patients with at least one NE out of 1000 patient admissions. A univariable analysis was performed to assess differences between patients who incurred at least one NE and those whose hospitalizations were free of NE. Continuous variables were compared using Student's *t* tests and categorical variables were compared using Rao–Scott Chi-square tests. Multivariable regression analysis was performed to assess factors associated with occurrence of NE as well as to evaluate the association between NE and in-hospital death, length of hospital stay, and hospital charges. Patient and hospital characteristics were included in the regression model along with the procedure

type. Multivariable logistic regression modeling was used for assessing NE and in-hospital death and multivariable linear regression modeling was used for assessing NE and length of hospital stay and hospital charges, adjusting for potential confounders, including age, gender, race, income by zip code, insurance type, diabetes, congestive heart failure, chronic pulmonary disease, renal failure, obesity, weight loss, paralysis, coagulopathy, fluid and electrolyte disorder, blood loss anemia, chronic deficiency anemia, valvular heart disease, depression, psychoses, elective vs. nonelective admission, weekend admission, hospital bed size, teaching status, urban vs. rural, geographic location of hospitals, and procedure type for TJA subgroups. We further compared NEs before and after 2008 to assess the temporal trend and the effect of the new CMS non-reimbursement policy on their occurrence.

The study was granted an exempt status by the institutional review board because of the de-identified quality of the data from the national database. All analyses were performed using SAS Survey Procedures software (version 9.4, The SAS Institute, Cary, NC). For all tests, a p value of less than 0.001 was considered statistically significant because of the large sample size.

Results

Between 2003 and 2012, there were a total of 8,176,774 patient admissions with TJA. A total of 5,124,207 (62.7%) patients underwent primary TKA, 2,353,319 (28.8%) patients underwent primary THA, 398,865 (4.9%) patients underwent revision TKA, and 300,383 (3.7%) patients underwent revision THA. The average age of this population was 65.9 ± 0.04 years. A total of 4,955,426 (60.7%) patients were female. The patients with NE, compared with those without NE, tended to be older, had more comorbid conditions, and had more weekend admissions (Table 1). There was a significantly higher mortality rate among the patients with NE (1.2%) as compared with those without NE (0.09%). The patients with NE had a significantly longer hospital stay (5.8 ± 0.04 days) as compared with those without NE (3.5 ± 0.01 days). In addition, the patients with NE incurred significantly higher hospital charges ($57{,}446.8 \pm 614.3$ dollars, inflation-adjusted charges) as compared with those among the patients without NE ($41{,}568.1 \pm 348.8$ dollars, inflation-adjusted charges) (Table 1).

The overall incidence of NE after TJA procedures in this cohort was 1.33%. 108,668 of the total 8,176,774 patients were recorded as having experienced at least one NE during admissions. The most prevalent NE was fall and trauma (0.7%), followed by deep vein thrombosis and pulmonary embolism (0.59%) (Fig. 1). Other NEs included catheter-associated urinary tract infection (0.02%), foreign body retained after surgery (0.012%), pressure ulcer stages III and IV (0.007%), vascular catheter-associated infection (0.003%), manifestations of poor glycemic control (0.003%), and iatrogenic pneumothorax with venous catheterization (0.002%). Air embolism, wrong-site operations, surgical site infection, and blood incompatibility were not recorded in this cohort of patients. A temporal comparison of NEs before and after 2008, when the CMS announced discontinuing payment for NE, revealed that a decrease occurred in fall and trauma (0.75% vs. 0.65%, $p < 0.001$) and an increase occurred in vascular catheter-associated infection (0.001% vs. 0.004%. $p < 0.001$). Overall, there was a decrease in the total NE occurrence after 2008 in this cohort (1.39% vs. 1.25%, $p < 0.001$) (Table 2).

In the multivariable logistic regression analysis of NE development, significant predictors with higher odds of developing at least one NE included weekend admission [odds ratio (OR), 99.9% CI (CI), 4.3 (3.1, 5.8), $p < 0.001$], weight loss [OR (CI), 2.8 (2.2, 3.5), $p < 0.001$], fluid electrolyte disorders [OR (CI), 1.9 (1.8, 2.0), $p < 0.001$], coagulopathy [OR (CI), 1.8 (1.6, 2.0), $p < 0.001$], and congestive heart failure [OR (CI), 1.6 (1.4, 1.8), $p < 0.001$] (Table 3). Among the procedure types, revision THA, compared with primary THA, had higher odds of developing NE [OR (CI), 2.1 (1.9, 2.3), $p < 0.001$]. In the multivariable model for outcomes in relation to NE (Table 4), NE was found to be independently predictive of increased perioperative mortality [OR (CI), 7.4 (5.6, 9.7), $p < 0.001$], as well as a longer hospital stay and higher total hospitalization charges.

Discussion

Our study identified perioperative predictors of NE in patients undergoing TJA. Among the TJA procedures, patients undergoing revision THA, in particular, were at higher odds of developing NE during hospitalization. Occurrence of NE was not only associated with higher perioperative mortality but also with a higher demand of medical and financial resources as shown by the association with an increased length of hospital stay and hospitalization costs.

NE has placed a significant financial burden on the US health care system [11–16]. Since the implementation of the nonpayment program by CMS, reducing NE occurrence and the associated financial penalty has been of particular interest to hospitals and organizations. The incidence of NE associated with surgical procedures varies considerably, depending on the specialty and patient groups [11]. Reducing preventable postoperative complications and improving patient safety have been the focus of recent health care reform [3, 4, 17, 18]. Although risk levels and disease complexity might be different by patient population and hospitals, CMS uses the same surgically relevant measure, such

Table 1 Never events and patient characteristics

Characteristic	Total ($N=8,176,774$)	No never events ($N=8,068,106$)	Never events ($N=108,668$)
Age (years)	65.9 ± 0.0	65.9 ± 0.0	67.9 ± 0.1
Age (years)			
18–44	259,934 (3.2)	256,840 (3.2)	3,094 (2.8)
45–64 years	3,295,552 (40.3)	3,257,813 (40.4)	37,740 (34.7)
65 + years	4,621,288 (56.5)	4,553,453 (56.4)	67,835 (62.4)
Gender			
Male	3,204,841 (39.3)	3,167,125 (39.3)	37,717 (34.7)
Female	4,955,426 (60.7)	4,884,498 (60.7)	70,928 (65.3)
Race			
White	5,505,434 (67.3)	5,434,638 (67.4)	70,796 (65.1)
Black	457,155 (5.6)	450,615 (5.6)	6540 (6.0)
Hispanic	282,607 (3.5)	278,587 (3.5)	4020 (3.7)
Other	230,588 (2.8)	227,462 (2.8)	3126 (2.9)
Unknown	1,700,990 (20.8)	1,676,804 (20.8)	
Primary expected payer			
Medicare	4,506,490 (55.2)	4,440,512 (55.1)	65,978 (60.8)
Medicaid	235,655 (2.9)	232,346 (2.9)	3309 (3.0)
Private insurance	3,116,647 (38.2)	3,081,866 (38.3)	34,781 (32.1)
Other	301,881 (3.7)	297,435 (3.7)	4446 (4.1)
Median household income quartile			
1	1,666,769 (20.8)	1,643,131 (20.7)	23,637 (22.2)
2	2,116,639 (26.4)	2,088,302 (26.4)	28,337 (26.6)
3	2,154,660 (26.8)	2,127,236 (26.8)	27,424 (25.7)
4	2,091,970 (26.1)	2,064,747 (26.1)	27,222 (25.5)
Admission month			
January–March	1,919,452 (25.3)	1,894,124 (25.3)	25,329 (25.2)
April–June	1,893,329 (24.9)	1,868,106 (24.9)	25,223 (25.1)
July–September	1,840,699 (24.2)	1,816,167 (24.2)	24,532 (24.4)
October–December	1,946,113 (25.6)	1,920,847 (25.6)	25,267 (25.2)
Weekend admission	33,965 (0.42)	31,715 (0.39)	2250 (2.1)
Elective admission	8,176,774 (100.0)	8,068,106 (100.0)	108,668 (100.0)
TJA type			
Primary THA	2,353,319 (28.8)	2,319,738 (28.8)	33,581 (30.9)
Primary TKA	5,124,207 (62.7)	5,064,806 (62.8)	59,401 (54.7)
Revision THA	300,383 (3.7)	290,684 (3.6)	9699 (8.9)
Revision TKA	398,865 (4.9)	392,878 (4.9)	5987 (5.5)
Coagulopathy	154,453 (1.9)	149,860 (1.9)	4593 (4.2)
H. pylori	810 (0.01)	767 (0.01)	43 (0.04)
Cirrhosis	19,503 (0.24)	19,101 (0.24)	401 (0.37)
Portal hypertension	1920 (0.02)	1843 (0.02)	
Ascites	451 (0.01)	441 (0.01)	10 (0.01)
Hepatic encephalopathy	620 (0.01)	563 (0.01)	56 (0.05)
Hepatorenal syndrome	127 (0.00)	127 (0.00)	0 (0)
Acute renal failure (including dialysis)	128,544 (1.6)	123,732 (1.5)	4812 (4.4)
Hypovolemia including shock	95,742 (1.2)	92,687 (1.1)	3055 (2.8)
Respiratory failure	18,407 (0.23)	16,416 (0.20)	1992 (1.8)
Coronary artery disease	1,117,403 (13.7)	1,100,425 (13.6)	16,978 (15.6)
Congestive heart failure	217,640 (2.7)	211,722 (2.6)	5918 (5.4)
Valvular heart disease	310,878 (3.8)	305,583 (3.8)	5295 (4.9)

Table 1 (continued)

Characteristic	Total ($N = 8,176,774$)	No never events ($N = 8,068,106$)	Never events ($N = 108,668$)
Pulmonary circulation disorders	72,931 (0.89)	44,448 (0.55)	28,483 (26.2)
Peripheral vascular disorders	156,719 (1.9)	153,662 (1.9)	3057 (2.8)
Paralysis	24,844 (0.30)	24,135 (0.30)	709 (0.65)
Other neurological disorders	265,134 (3.2)	259,634 (3.2)	5500 (5.1)
Chronic pulmonary disease	1,153,065 (14.1)	1,135,244 (14.1)	17,821 (16.4)
Diabetes, uncomplicated	1,390,035 (17.0)	1,371,476 (17.0)	18,560 (17.1)
Diabetes with chronic complications	110,578 (1.4)	108,681 (1.3)	1897 (1.7)
Hypothyroidism	1,134,775 (13.9)	1,119,041 (13.9)	15,734 (14.5)
Renal failure	237,515 (2.9)	232,914 (2.9)	4602 (4.2)
Liver disease	66,830 (0.82)	65,748 (0.81)	1082 (1.00)
Peptic ulcer disease excluding bleeding	2151 (0.03)	2115 (0.03)	35 (0.03)
Acquired immune deficiency syndrome	4721 (0.06)	4609 (0.06)	112 (0.10)
Lymphoma	21,458 (0.26)	21,038 (0.26)	420 (0.39)
Metastatic cancer	7565 (0.09)	7276 (0.09)	289 (0.27)
Solid tumor metastasis	31,214 (0.38)	30,582 (0.38)	632 (0.58)
Rheumatoid arthritis/collagen vascular diseases	301,294 (3.7)	296,662 (3.7)	4631 (4.3)
Obesity	1,317,197 (16.1)	1,299,903 (16.1)	17,294 (15.9)
Weight loss	21,536 (0.26)	20,111 (0.25)	1425 (1.3)
Fluid electrolyte disorders	631,987 (7.7)	614,580 (7.6)	17,407 (16.0)
Chronic blood loss anemia	149,504 (1.8)	146,500 (1.8)	3003 (2.8)
Iron deficiency anemia	1,085,141 (13.3)	1,064,968 (13.2)	20,173 (18.6)
Alcohol abuse	77,445 (0.95)	75,965 (0.94)	1480 (1.4)
Drug abuse	35,166 (0.43)	34,507 (0.43)	659 (0.61)
Psychoses	134,150 (1.6)	131,870 (1.6)	2280 (2.1)
Depression	873,830 (10.7)	860,793 (10.7)	13,037 (12.0)
Hypertension	5,193,036 (63.5)	5,124,722 (63.5)	68,314 (62.9)
No. of Elixhauser's comorbidities			
0	1,299,029 (15.9)	1,287,935 (16.0)	
1	2,379,683 (29.1)	2,357,852 (29.2)	21,831 (20.1)
2	2,182,450 (26.7)	2,155,220 (26.7)	27,230 (25.1)
3 +	2,315,613 (28.3)	2,267,099 (28.1)	48,513 (44.6)
CCI			
0	5,077,736 (62.1)	5,015,972 (62.2)	61,765 (56.8)
1	2,205,596 (27.0)	2,174,863 (27.0)	30,734 (28.3)
2	626,960 (7.7)	616,372 (7.6)	10,588 (9.7)
3 +	266,482 (3.3)	260,900 (3.2)	5582 (5.1)
Hospital in urban location	7,231,496 (88.8)	7,135,842 (88.8)	95,654 (88.3)
Teaching hospital	3,507,406 (43.0)	3,459,233 (43.0)	48,173 (44.5)
Bed size of hospital			
Small/medium	3,342,073 (41.0)	3,298,089 (41.0)	43,984 (40.6)
Large	4,805,330 (59.0)	4,741,032 (59.0)	64,298 (59.4)
Region of hospital			
Northeast	1,508,530 (18.4)	1,490,681 (18.5)	17,849 (16.4)
Midwest	2,251,896 (27.5)	2,220,920 (27.5)	30,976 (28.5)
South	2,821,555 (34.5)	2,781,144 (34.5)	40,411 (37.2)
West	1,594,793 (19.5)	1,575,361 (19.5)	19,432 (17.9)
RBC transfusion	1,181,473 (14.4)	1,150,691 (14.3)	30,782 (28.3)
Endotracheal intubation	16,309 (0.20)	14,530 (0.18)	1778 (1.6)
Mechanical ventilation (> 96 h)	4358 (0.05)	3711 (0.05)	647 (0.60)

Table 1 (continued)

Characteristic	Total ($N=8,176,774$)	No never events ($N=8,068,106$)	Never events ($N=108,668$)
Central venous access procedures	82,424 (1.01)	77,833 (0.96)	4591 (4.2)
Endoscopic treatment with intervention	1327 (0.02)	1216 (0.02)	110 (0.10)
Endoscopic treatment without intervention	16,880 (0.21)	15,980 (0.20)	899 (0.83)
Endoscopic treatment	17,687 (0.22)	16,720 (0.21)	967 (0.89)
Surgery for treatment of bleeding ulcer	115 (0.00)	105 (0.00)	10 (0.01)
Colonoscopy	3676 (0.04)	3428 (0.04)	247 (0.23)
In-hospital death	8371 (0.10)	7080 (0.09)	1292 (1.2)
Length of stay (days)	3.5 ± 0.01	3.5 ± 0.01	5.8 ± 0.04
Inflation-adjusted charges (2013$)	41,779.6 ± 350.0	41,568.1 ± 348.8	57,446.8 ± 614.3

Categorical data presented as weighted frequency (%) and continuous data as mean ± standard deviation unless otherwise stated

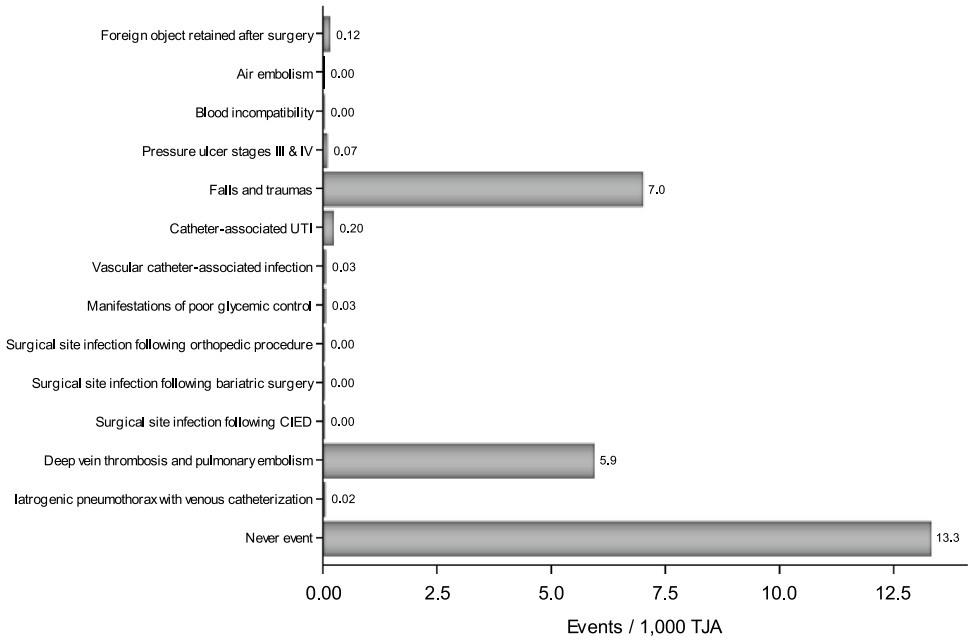

Fig. 1 Prevalence of never events in the hospitalized patients with total joint arthroplasty

Table 2 Never events before and after 2008 in the hospitalized patients with total joint arthroplasty

Event	2003–2007	2009–2012	*p* value
Foreign object retained after surgery	0.14	0.10	0.074
Air embolism	0.00	0.00	–
Blood incompatibility	0.00	0.00	–
Pressure ulcer stages III and IV	0.00	0.14	–
Falls and traumas	7.5	6.5	< 0.001
Catheter-associated urinary tract infection	0.17	0.21	0.14
Vascular catheter-associated infection	0.01	0.04	< 0.001
Manifestations of poor glycemic control	0.04	0.03	0.36
Surgical site infection following orthopedic procedure	0.00	0.00	–
Deep vein thrombosis and pulmonary embolism	6.0	5.5	0.063
Iatrogenic pneumothorax with venous catheterization	0.03	0.01	0.083
Never events, total	13.9	12.5	< 0.001

Number of never events per 1000 total joint arthroplasty

Table 3 Independent risk factors associated with never events in the hospitalized patients with total joint arthroplasty

Variable	OR (99.9% CI)	*p* value
Age (years)	1.08 (1.06, 1.09)	< 0.001
female vs. male	1.2 (1.1, 1.2)	< 0.001
Race		
Black vs. white	1.10 (0.98, 1.2)	0.006
Hispanic vs. white	1.2 (1.01, 1.3)	< 0.001
Other vs. white	1.06 (0.91, 1.2)	0.19
Unknown vs. white	1.1 (1.01, 1.2)	< 0.001
Median household income quartile		
2nd vs. 1st quartile	0.97 (0.91, 1.05)	0.24
3rd vs. 1st quartile	0.95 (0.88, 1.03)	0.036
4th vs. 1st quartile	1.00 (0.91, 1.09)	0.86
Primary expected payer		
Medicaid vs. medicare	1.2 (1.03, 1.4)	< 0.001
Private insurance vs. medicare	1.04 (0.97, 1.1)	0.060
Other vs. medicare	1.4 (1.2, 1.6)	< 0.001
Weekend admission	4.3 (3.1, 5.8)	< 0.001
Congestive heart failure	1.6 (1.4, 1.8)	< 0.001
Valvular heart disease	1.07 (0.96, 1.2)	0.034
Chronic pulmonary disease	1.1 (1.05, 1.2)	< 0.001
Diabetes, uncomplicated	0.97 (0.91, 1.04)	0.17
Diabetes with chronic complications	1.09 (0.91, 1.3)	0.13
Renal failure	1.02 (0.90, 1.2)	0.54
Coagulopathy	1.8 (1.6, 2.0)	< 0.001
Obesity	1.05 (0.98, 1.1)	0.021
Weight loss	2.8 (2.2, 3.5)	< 0.001
Fluid electrolyte disorders	1.9 (1.8, 2.0)	< 0.001
Chronic blood loss anemia	1.4 (1.2, 1.6)	< 0.001
Iron deficiency anemia	1.3 (1.2, 1.4)	< 0.001
Psychoses	1.2 (1.03, 1.4)	< 0.001
Depression	1.1 (1.02, 1.2)	< 0.001
Hospital in urban location	0.91 (0.81, 1.02)	0.005
Teaching hospital	1.06 (0.97, 1.2)	0.034
Bed size of hospital		
Large vs. small/medium	0.98 (0.90, 1.06)	0.35
Region of hospital		
Midwest vs. northeast	1.1 (0.94, 1.3)	0.042
South vs. northeast	1.2 (1.02, 1.4)	< 0.001
West vs. northeast	1.01 (0.87, 1.2)	0.75
TJA type		
Primary TKA vs. primary THA	0.80 (0.74, 0.86)	< 0.001
Revision THA vs. primary THA	2.1 (1.9, 2.3)	< 0.001
Revision TKA vs. primary TKA	0.99 (0.89, 1.1)	0.79

OR odds ratio, *CI* confidence interval

Table 4 Association of never events with outcomes in the hospitalized patients with total joint arthroplasty

Label	Estimate (99.9% CI)	*p* value
Odds of dying associated with never event	7.4 (5.6, 9.7)	< 0.001
Mean difference in length of stay	2.0 (1.9, 2.2)	< 0.001
Mean difference in costs	13,554.85 (12,171.35, 14,938.35)	< 0.001

Adjusted for age, gender, race, income by zip code, insurance type, diabetes, congestive heart failure, chronic pulmonary disease, renal failure, obesity, weight loss, paralysis, coagulopathy, fluid and electrolyte disorder, blood loss anemia, chronic deficiency anemia, valvular heart disease, depression, psychoses, elective vs. nonelective admission, weekend admission, bed size, teaching status, urban/rural, and geographic location of hospital

as NE, to assess health care quality and patient safety for surgeons and hospitals. It is important to measure the quality based on the same definition as CMS when studying high-volume surgical procedures such as THA and TKA. Our study found that approximately 1.0% of patients undergoing TJA experienced one or more NE during their hospital stays in the United States, with inpatient fall and trauma the most common individual NE followed by deep vein thrombosis and pulmonary embolism.

The second aim of the study was to identify patient characteristics and hospital factors associated with NE development after TJA procedures. Previous research has noted that certain patient characteristics were associated with NE, such as patent age, race, number of preadmission comorbidities [19–25]. In the present study on TJA patients, several independent patient risk factors were found to be associated with NE development after TJA procedures, most notably increasing age, female gender, and comorbid conditions including congestive heart failure, chronic pulmonary disease, coagulopathy, weight loss, fluid electrolyte disorders, anemia, psychosis, and depression. Many of these risk factors are not modifiable. Older patients were at higher risk for NE as they are at higher risk for a variety of complications [19]. Some factors, such as race and ethnicity, which were not documented in the discharge information in certain states in the United States, were often difficult to evaluate as they may be influenced by disparities in accessing health care. On the other hand, some hospital factors in association with NE may be modifiable. Our present study revealed that patients with weekend admission for TJA procedures had approximately four times higher odds of developing NE during their hospital stays than those with weekday admissions. The identification of modifiable hospital factors as a preventive measure is important and is congruent with the suggestions that risk adjustment should be made for hospitals that admit the patients and consistently take care of them during their hospital stays [26–28]. Previous reports on hospitals participating in the HAC Reduction Program in the United States suggested that larger accredited hospitals, in

spite of better clinical care measures in place, might have more complex patients, and, therefore, might have a higher incidence of NE because of the disease complexities of these patients [22, 28]. However, our study from this large national representative database found that bed size of hospital, hospital in urban location, and teaching status of hospital were not associated with NE development.

Despite the clinical success of TJA, the number of revision TJA performed in the United States has increased with time. The revision burden for THA is 52% greater than for TKA [6, 7, 25]. The etiology of the increase is multifactorial [29–35]. Studies showed that patients undergoing revision THA tended to be older and sicker [16, 36–38]. Our study revealed that among the procedure types, revision THA, compared with primary THA, was associated with higher odds of developing NE.

There are limitations in the present study. This is a retrospective study using administrative database, which is inherently subject to biases. The NIS database recorded procedures and diagnoses using ICD-9-CM codes which may be subject to differential, non-random, misclassification in coding. As they were entered by administrators, the procedure information may not be available in the database if a code was omitted from a patient encounter clinical note. The NIS database did not include data generated after the inpatient episode of care. Conditions and outcomes that could only be observed with extended follow-up after patient discharge were outside the scope of this study. Thus, it is possible that the incidence of morbidity and mortality associated with NE after TJA might be underestimated. In addition, there was a difficulty with temporal discernment in NIS database whether or not a recorded NE was a result of a surgical procedure or a pre-existing condition noted after the procedure. Nonetheless, because NE occurrence is rare, which makes a prospective study or clinical trial unrealistic, retrospective analyses in a large database can provide useful information for developing preventive strategies.

In conclusion, our data demonstrated that NE in TJA patients was predictive of an increased mortality, length of hospital stay, and hospitalization costs. This study established baseline NE rates in the TJA patient population to use as benchmarks and identified target areas for quality improvement in US. Further research is needed to evaluate the interventions to decrease the risk for NE in this patient population.

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Compliance with ethical standards

The study was granted an exempt status by the institutional review board because of the de-identified quality of the data from the national database

Conflict of interest The authors declare no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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