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Patient versus Provider Characteristics Impacting Hospital Lengths of Stay Following Total Knee or Hip Arthroplasty

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Abstract

Introduction—This study aims to identify whether patient-level or provider-level characteristics are most influential on a patient's length of stay in the acute care hospital.

Materials and Methods—A dataset containing a nationally representative sample of inpatient discharge abstracts was used. Multi-level linear regression models were used to evaluate the associations between patient- and provider-level characteristics on patients' lengths of stay.

Results—The target population included 322,894 discharges with a primary procedure code for primary total knee arthroplasty and 193,553 discharges for total hip arthroplasty. The variables associated with the greatest increases in length of stay were a higher co-morbidity level among patient level attributes (+17.4%) and low surgeon volume among provider-level characteristics (+18.8%).

Discussion—Provider-level characteristics, particularly provider volume, had a greater impact on length of stay.

INTRODUCTION

The prevalence of arthritis and joint pain has risen in the overall US population, from 11.0% in 1996 to 12.9% in 2004.¹ Lower extremity total joint arthroplasties have been repeatedly demonstrated to be efficacious and cost-effective methods for treating end-stage arthritis.²⁻⁵ Between 1993 and 2002, the rates of primary hip and knee arthroplasty procedures increased

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by 35% and 70%, respectively, however by 2030, the rates are expected to be nearly 174% and 673% times higher than the 2005 rates.^{4, 6} Understanding the influence of specific baseline demographic characteristics on outcomes including hospital length of stay in patients undergoing arthroplasty may inform pre-operative planning to optimize discharge planning, rehabilitative resources and outcomes. By anticipating shorter or longer lengths of stay, patients may be more accurately counseled pre-operatively to appropriately manage patient and family expectations of their hospital stay.

A number of recent studies have demonstrated a relationship between patient, surgeon, and hospital characteristics and the patient's risk for developing post-operative complications. Higher volume surgeons and hospitals experience lower mortality rates than lower volume surgeons and centers.⁷⁻⁹ Previous research has demonstrated the importance of both surgeon and hospital volume in determining the outcome of total joint arthroplasty.^{8, 10, 11} Higher provider volumes have been similarly linked to improved surgical outcomes in other specialties as well.⁷ Additionally, it has been shown that patient characteristics have a greater influence on the development of post-operative complications than hospital characteristics.¹² African-Americans have higher rates of morbidity, mortality and readmission compared to Caucasians following total hip arthroplasty (THA) and total knee arthroplasty (TKA).^{13, 14} The development of complications is associated with prolonged lengths of stay and increased hospital costs.¹⁵ This study directly compares the effects of the patient and provider characteristics to determine which is more important in influencing length of stay while adjusting for the effects of other covariates. Identifying sources of prolonged lengths of stay in total joint arthroplasties could provide targets for cost-saving opportunities.

MATERIALS AND METHODS

The study was a cross-sectional secondary data analysis of a national administrative database. Parallel studies employing an identical methodological approach were conducted separately for TKA and THA cases. This study was approved by the hospital's Institutional Review Board.

Sponsored by the Agency for Healthcare Research and Quality, the 2002 Health Care Utilization Project-Nationwide Inpatient Sample (HCUP-NIS) is an annual nationally representative stratified sample of community hospitals in states contributing to the HCUP. The sampling strategy was designed to select hospitals representing 20% of the discharges in each hospital characteristic stratum (i.e. region, urban/rural location, number of beds, teaching status, and ownership/control). Once a hospital was selected for inclusion in the database, 100% of that hospital's discharges were included. The database includes over seven-million discharges from hospitals in thirty-five states and provides sampling weights allowing the data to be representative of national trends.

Study population

Cases were selected from the entire HCUP-NIS database based on having a primary procedure code of either primary TKA or THA according to the International Classification of Diseases, 9th Clinical Modification procedure of 81.54 and 81.51 respectively. This resulted in 73,350 TKA discharges and 42,131 THA discharges (Figure 1).

Exclusion criteria included: the patient was undergoing a concurrent lower-extremity joint arthroplasty procedure (bilateral knee arthroplasty, hip and knee arthroplasty, or bilateral total hip arthroplasty); the discharge record carried diagnosis codes suggestive of knee or thigh infections, of a previous arthroplasty, complication from a previous arthroplasty, or of a pathological fracture⁸; the length of stay for a particular discharge fell in the outlier range

(representing 0.04% and 0.11% from each tail of the distribution of the knee arthroplasty and the hip arthroplasty cases respectively); the patient was less than 18 years old. These exclusion criteria yielded 67,713 primary TKA discharges and 40,333 primary THA discharges, representing 322,894 primary TKA cases and 192,553 primary THA cases after applying the discharge weights (Figure 1).

Main Outcome Measures

The primary dependent variable of interest was a patient's length of stay, in days, in the acute care hospital, from the date of admission to the date of discharge. Due to its right-skewed distribution, a logarithmic transformation of the patient's length of stay was used as the primary outcome of interest. This log transformation resulted in a normal distribution imperative for the linear modeling.¹⁶

In a secondary analysis, the hospital charges associated with the discharges were evaluated to estimate the amount associated with each additional day in a patient's hospital stay. Cases incurring charges amounting in the top and bottom 1% of charges were excluded from this secondary analysis. In order to obtain a normal distribution, a logarithmic transformation of the hospital charges was performed and then used as the outcome in the regression model. The transformed outcome variable in the model required a re-transformation according to the peer-reviewed methods to produce the mean change in hospital charges associated with each additional day in the hospital stay.¹⁷

Main Effects

Independent variables evaluated for an association with length of stay included patient-level and provider-level characteristics. The patient-level characteristics evaluated included age, gender, race, Deyo¹⁸ adjusted Charlson comorbidity index, household income at the ZIP code level, and insurance status. A reference case was constructed for comparison. The reference case was a young (under 60) white male¹³, with a Charlson comorbidity score of zero¹⁹, with private insurance, and having a household income of \$45,000 or more per year. Age was categorized according to quartiles as shown in Table 1. Race was missing from a substantial portion of the records due to 11 of the 35 states in the dataset not reporting race at all. As a result, the records without a value for race did not appear to represent a distinct racial group that was underrepresented but a factor of the states not reporting race. For the cases missing a race value, a dummy value for race was created to distinguish these patients and prevent their being dropped from the analysis. As a result, the race variable was categorized into four groups: white, black, other (Hispanic, Asian, Native American and other), and missing in an attempt to increase the statistical power of minority patient groups. Charlson comorbidity scores were split into 3 categories, a score of 0, 1 and greater than or equal to 2. A score of 0 does not indicate that the patient did not have any comorbidity; rather that none of the documented diagnosis codes could count towards the Charlson index. The insurance payer analyzed was only the primary payer listed for the discharge except for dual Medicare/Medicaid enrollees who were identified by looking at both the primary and secondary insurers. The "Other" insurance status included patients listed as "self-pay" or "no-charge."

Provider-level characteristics analyzed included geographic region (Northeast, South, Midwest, West), location (Urban/Rural), teaching status (Teaching/Non-teaching), bed size (Small, Medium, Large), hospital ownership structure (public, private non-profit, private for-profit), surgeon volume of knee or hip arthroplasty procedures, and hospital volume of knee or hip arthroplasty procedures. The actual number of beds required to be classified as small, medium, or large varied according to the region and setting of the hospital, but these values were standardized in the HCUP-NIS dataset. The reference provider selected was an

urban, non-teaching hospital in the northeastern US, with a low number of beds (small) but a high volume surgeon in a high volume non-profit center.

Two variables of interest, surgeon and hospital volumes of THA and TKA, were derived by using the synthetic physician and hospital identifiers associated with each discharge. Surgeon and hospital volumes were determined by counting the number of times a specific physician or hospital was identified in the dataset for having performed one of the total joint arthroplasty operations. Since the dataset is a 20% sample stratified at the hospital level, but contains 100% of the discharges from the sampled hospitals, this approach was believed a valid method of capturing surgeon and hospital volumes. This means that the dataset contains only a select number of hospitals within a state to obtain one-fifth of all discharges within that state, but every single discharge from an included hospital was listed in the dataset. As with the patient's race variable, surgeon codes were missing from 39.1% of TKA cases and 40.5% THA cases due to 12 of the 35 states not reporting the provider identification. The surgeon and hospital variables were then categorized based on quartiles in order to give meaningful cut-points to variations in volume. A fifth category of 'Missing' was added to the surgeon volume variable in order to retain cases in the analysis from the 12 states which did not associate discharges with a surgeon identifier.

Statistical Methods

Associations between the patient-level and provider-level variables were evaluated using chi-square and ANOVA tests for categorical and continuous variables, respectively. Univariate analyses were then conducted evaluating unadjusted variations in length of stay associated with each of the patient- and hospital-level characteristics. These analyses were conducted using SAS version 9.1 (SAS Institute Inc., Cary, NC) which allowed for the sampling weights from the data collection to be taken into account.

The effects of patient-level and provider-level characteristics were evaluated simultaneously in a 2-level hierarchical linear model in order to distinguish the independent effects from each level of variables on the continuous outcome, length of stay. The first level was the patient-level variables and the second level was comprised of the provider-level variables. In these multivariable models, the effects of each independent variable were evaluated while adjusting for all of the patient-level and provider-level variables

In a separate 2-level hierarchical linear model, length of stay was added to the model as an independent variable along with all of the previously included variables, while the outcome of interest was hospital charges associated with the discharges. The effect of each additional day in a patient's length of stay on the hospital charges was then ascertained while adjusting for all of the patient-level and provider-level variables. These various multi-level analyses were conducted using HLM version 6 (SSI Inc., Lincolnwood, IL).

RESULTS

The patients were predominantly white (over 80%) and female (over 55%) in each of the procedure groups (Table 1). The mean age of patients undergoing TKA was slightly higher (67.4 years) than patients undergoing THA (65.8 years). While women outnumbered men in both procedures, this was especially evident among TKA patients (64.59% versus 57.72%). The populations undergoing primary joint arthroplasty operations did not have a significant comorbidity burden reflected by approximately 70% of patients for either procedure having Charlson Comorbidity Index scores of zero. The mean length of stay was slightly greater when undergoing a THA compared to TKA (3.90 days versus 3.74 days).

Many of the patient characteristics were associated with certain provider-level variables (Tables 2 and 3). The percentages given in Tables 2 and 3 represent the proportion of that patient characteristic seen within the hospital characteristic level, as a result, the proportions do not add to 100%. There was substantial variation in the patient populations treated by different strata of providers. In particular, providers differed in their patient population's composition of race, income level, and comorbidity score. Among both TKA and THA providers, low volume surgeons had higher proportions of black patients. Black patients also comprised higher proportions of the populations for urban and teaching hospitals. Poorer patients comprised a larger proportion of the patients treated for TKA and THA in rural, non-teaching hospitals and by low volume surgeons. Patients with higher comorbidity scores were more likely to be treated at hospitals with a higher number of beds. Surprisingly, low volume surgeons for both TKA and THA had patient populations with slightly higher comorbidity burdens (Tables 2 and 3).

According to the unadjusted analyses, almost every patient and provider characteristic evaluated was associated with statistically significant extended lengths of stay, with similar results for both TKA and THA (Table 4).

In the adjusted multi-level regression models, many of the patient and provider characteristics were no longer significantly associated with extended lengths of stay (Table 5). Females stayed longer than their male peers (TKA: +2.0%; THA: +2.6%). Individuals over 75 years old stayed longer than their younger counterparts (TKA: +5.3%; THA: +8.4%). Black patients stay slightly longer than whites (TKA: +3.5%; THA: +5.6%). Not surprisingly, sicker patients stay longer in the hospital. Compared to patients with a comorbidity score of zero, patients with a comorbidity score of 1 stayed slightly longer (TKA: +4.5%; THA: +5.6%) while patients with comorbidity scores of 2 or more stayed considerably longer (TKA: +12.4%; THA: +17.4%). Income levels were not consistently associated with prolonged lengths of stay. Among THA patients, individuals in the lowest income level stayed the longest (+3.8%). Individuals with private insurance had the shortest stays in the hospital. Medicaid patients had the longest stays (TKA: +8.8%; THA: +10.3%).

Fewer provider characteristics significantly impacted the patient's length of stay (Table 3). Factors that were not significant included most geographic regions, a rural versus urban setting, teaching status, size, and ownership status (i.e. whether the hospital is public, private for-profit, or private non-profit). Two variables that were highly significant predictors of length of stay were the annual volume of that procedure performed by the surgeon and the center. The centers in the lowest volume quartile (TKA: <100 cases per year; THA: <64 cases per year) had patients stay longer (TKA: +11.3%; THA: +14.6%) than the centers in the highest volume quartile (TKA: ≥294 cases per year; THA: ≥225 cases per year). Surgeon volumes also had a great effect on the patient's length of stay. Patients treated by surgeons in the lowest volume quartile (TKA: <17 cases per year; THA: <10 cases per year) stayed longer (TKA: +10.8%; THA: 18.8%) than the patients of surgeons in the highest volume quartile (TKA: ≥67 cases per year; THA: ≥53 cases per year).

The regression model evaluating the effect of each additional day of a patient's length of stay on marginal charges by the hospital showed each additional day was responsible for roughly an 8% increase in hospital charges (TKA: +8.9%; THA: +7.8%, $p < 0.001$).

DISCUSSION

Our findings suggest that surgeon volume had as great, if not a greater effect, on a patient's length of stay as their co-morbidity score. In addition, the institution's volume of that procedure had a considerable impact on the patients' length of stay. When combining the

surgeon with the hospital, the provider's volume of the procedure has the largest effect on a patient's length of stay. For example, a TKA patient who might otherwise have an anticipated length of stay of 4 days, when treated by a low-volume surgeon in a low-volume hospital could anticipate a length of stay of 4.88 days. For a THA patient, the effect of low-volume surgeons and hospitals is even more pronounced, when an anticipated length of stay of 4 days would be extended to 5.34 days.

It has been shown that a prolonged length of stay is often the result of developing complications.¹⁵ Studies have demonstrated that age, gender, race, Charlson comorbidity index, income level, insurance type, and hospital volume are all associated with the development of complications following TKA and THA.^{12, 20} This study demonstrates that the annual volume of that procedure performed by the surgeon and hospital has as great or a greater impact on the patient's length of stay than the patient's characteristics. The finding that high volume providers having shorter lengths of stay is not surprising considering the literature supporting these surgeons and hospitals have superior outcomes.^{8, 10-12}

A disparity in access to and utilization of total joint arthroplasty in the US has been described. African-Americans and women are more reluctant than Caucasians and men to choose a TKA.²¹ Despite this reluctance, women remain the predominant recipients of total knee and hip replacements since osteoarthritis is more prevalent in women. African-Americans and Hispanics have a similar prevalence of osteoarthritis to Caucasians, however minorities undergo total joint arthroplasty at lower rates than Caucasians.^{4, 22, 23} Patients of lower socioeconomic status also undergo total joint replacements at lower rates than their wealthier peers.²⁴ Our results demonstrate that once a minority or a low income individual elects to undergo a joint replacement, she is more likely to be treated by a low volume surgeon. This is notable since these minority and low income patients are at greater risk for developing complications and appear to be more frequently treated by the providers with inferior outcomes. Since total joint arthroplasty operations are typically an elective, non-emergent procedure, future research may be necessary to identify why these patients tend to receive treatment from low volume providers if we hope to decrease disparities in length of stay.

Other factors influencing the patient's length of stay may have very little to do with the patient herself, including insurance status and geographic region. Administrative factors may be the underlying reason a patient's insurance status impacts the patient's length of stay. Many insurers pay lump sums for a procedure regardless of the duration of a patient's hospital stay, thus encouraging hospitals to discharge the patient sooner for cost-savings. In contrast, Medicare requires minimum lengths of stay in the hospital, including a three day minimum stay prior to being discharged to a rehabilitation facility in order to avoid the hospital facing a reimbursement penalty.²⁵ These administrative characteristics of the insurance plans may play a greater role in the length of stay differences between public and private insurance than the characteristics of the patients enrolled in each plan. It has been documented for several years that regional variations in length of stay exist.^{26, 27}

One potential explanation for the study's findings may be that the higher volume centers are simply more efficient at cost-shifting by discharging their patients to inpatient rehabilitation facilities earlier. Between 1997 and 2007, the average length of stay following a total hip or knee arthroplasty decreased (4.7 days to 3.7 days) while simultaneously there was a corresponding increase in the percentage of total hip or knee arthroplasty patients discharged to extended care facilities or home health care (69.3% to 75.9%) as opposed to being discharged home with outpatient physical therapy.²⁸ It has been demonstrated with other diagnoses and surgical procedures that hospitals with higher volume and hospitals affiliated with an inpatient extended care facility or a home health network are more likely to

discharge patients to those care facilities.^{29, 30} In a 2006 article though, Bozic et al. found that older, sicker, and Medicare insured patients were more likely to be discharged to an extended care facility following a total joint arthroplasty procedure.³¹ While cost-shifting is a reasonable concern when evaluating earlier discharges, the patient characteristics associated with an increased likelihood of being discharged to an extended care facility were also associated with prolonged lengths of stay in our analysis.

This study found that each additional day in a patient's length of stay was associated with an 8% increase in hospital charges. Some researchers have suggested that reducing length of stay is not economically significant for the patient since the final day of hospitalization is only associated with 6.8% of the total cost for a patient whose length of stay is four days.³² Considering the nation spent \$11.9 billion on TKAs in 2003, a reduction of even 6.8% poses a significant cost-savings opportunity for the health care system.³³

Hospitals face a financial burden associated with unnecessarily long patient stays and have gradually discharged patients at earlier time points in recent years.^{25, 28} Reducing lengths of stay is a primary driver of reducing hospital costs associated with total joint arthroplasty procedures.^{34, 35} The results of this study can be used to develop an appropriate timeline for anticipated discharge based upon the patient and provider's characteristics. This timeline can be used to facilitate making appropriate arrangements for post-acute care in advance of the patient actually being prepared for discharge, thus avoiding last minute administrative obstacles to discharge. The results of this study can also be used by hospitals for quality assurance measures to evaluate whether their patients' lengths of stay are simply due to the demographics of the hospital's patient population or if the lengths of stay are artificially high due to systemic issues.

The primary limitation in this study is that HCUP-NIS is a cross-sectional database without patient identifiers, thus it is impossible to determine adverse events post-discharge. The same patient may have been readmitted to the hospital immediately after discharge, but it would appear as two separate entries and interpreted as two separate individuals in the database. This limited the ability to accurately determine if patients discharged prematurely may have been readmitted, as this would have been undetected within the database. In addition, while the lengths of stay are reported as integers in the database, treating length of stay as a continuous variable allowed for greater sensitivity for detecting variations between patient groups. However, a 10% longer length of stay is more pertinent to the health care system than the individual patient. Whether a patient's prolonged length of stay is a result of the development of complications or difficulty in post-acute care accommodation arrangements is not possible to discern in the dataset. The variations could represent certain segments of the population reluctant to leave the safety of the hospital despite being physically capable of being discharged.

While these variations in lengths of stay may be difficult for the clinician to readily appreciate in their daily practice, clinicians can appreciate inefficiencies in the health care system. Centralizing sites for patients undergoing THA or TKA may provide an opportunity for cost-savings by minimizing the financial burden on the health care system due to prolonged hospital stays. While from a health care system perspective, it may be most cost-effective to limit arthroplasty procedures to high volume centers, from the patient's perspective, this may involve having to travel large distances away from friends and family to undergo the procedure by an unfamiliar surgeon. Since our system continues to utilize third-party payers, insurers may require patients to do more than use convenience as a reason to justify their selection of a surgeon. As our healthcare system comes under greater price scrutiny, administrators will be more reluctant to pay higher prices for less efficient care. In order for lower volume surgeons to continue competing with high volume centers,

they will likely need to adopt the high volume centers' methods for more efficient discharges of patients post-operatively.

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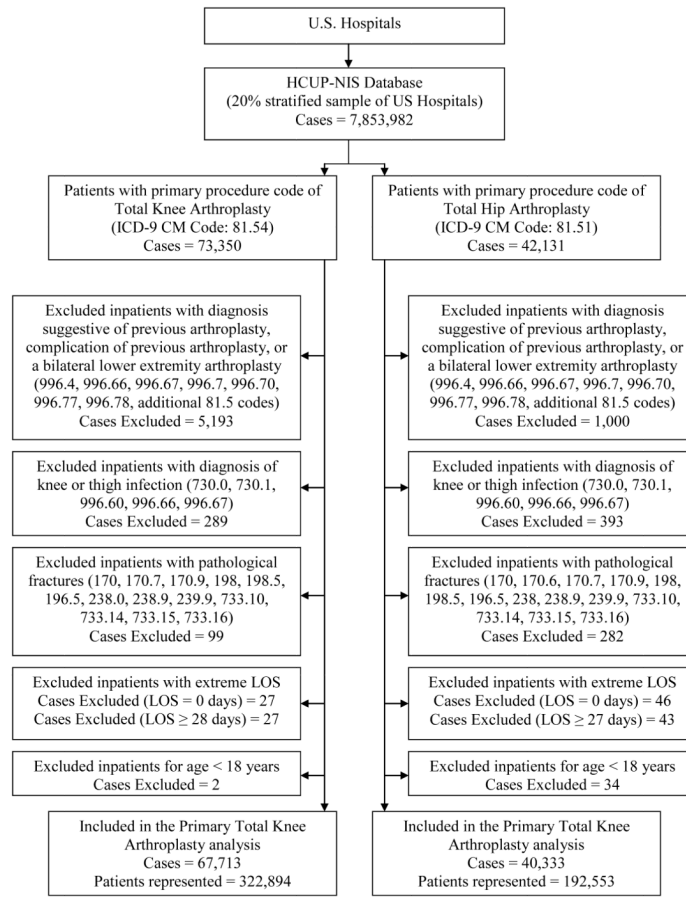


Figure 1.
Schema of Case Inclusion and Exclusion

The figure is a schematic representation of how the HCUP-NIS data file was pruned to two separate data files consisting of the primary TKR and THR cases. Arrows represent the step by step progression of exclusion, noting the number of cases excluded at each step, prior to obtaining the final set of cases meeting all inclusion and exclusion criteria.

Table 1

Baseline Characteristics of patients with a primary procedure code for either lower extremity total joint arthroplasty

Baseline Characteristics: Values given are frequencies with (%) unless noted.	Primary Total Knee Arthroplasty N = 322,894	Primary Total Hip Arthroplasty N = 192,553
Patient-level variables		
Age – median (IQR)	68 (60, 75)	68 (57, 76)
- 18-59	76,399 (23.66%)	58,542 (30.40%)
- 60-67	75,509 (23.38%)	36,373 (18.89%)
- 68-74	80,308 (24.87%)	40,549 (21.06%)
- 75+	90,679 (28.08%)	57,088 (29.65%)
Gender		
- Male	114,333 (35.41%)	81,404 (42.28%)
- Female	208,556 (64.59%)	111,140 (57.72%)
Race		
- White	186,669 (57.81%)	116,106 (60.30%)
- Black	16,786 (5.20%)	8,676 (4.51%)
- Hispanic	12,945 (4.01%)	4,356 (2.26%)
- Asian/Pacific Islander	2,210 (0.68%)	1,021 (0.53%)
- Native American	458 (0.14%)	216 (0.11%)
- Other	3,840 (1.19%)	2,058 (1.07%)
- Missing	99,986 (30.97%)	60,120 (31.22%)
Charlson Score		
- 0	216,431 (67.03%)	135,660 (70.45%)
- 1	81,679 (25.30%)	43,046 (22.36%)
- 2+	24,784 (7.68%)	13,848 (7.19%)
Income level		
- \$1-24,999	9,668 (2.99%)	5,056 (2.63%)
- \$25,000-34,999	59,780 (18.51%)	29,596 (15.37%)
- \$35,000-44,999	85,242 (26.40%)	46,519 (24.16%)
- ≥\$45,000	161,058 (49.88%)	107,238 (55.69%)
- Missing	7,146 (2.21%)	4,144 (2.15%)
Insurance Status (Primary payer):		
- Private	106,892 (33.12%)	73,194 (38.03%)
- Medicare	196,317 (60.83%)	108,971 (56.62%)
- Medicaid	7,632 (2.37%)	5,242 (2.72%)
- Dual Medicare/Medicaid*	15,665 (4.85%)	9,056 (4.70%)
- Other (incl. Self-pay)	11,908 (3.69%)	5,076 (2.62%)
Provider-level variables		

Baseline Characteristics: Values given are frequencies with (%) unless noted.	Primary Total Knee Arthroplasty N = 322,894	Primary Total Hip Arthroplasty N = 192,553
Hospital Region		
- Northeast	59,306 (18.37%)	42,108 (21.87%)
- Midwest	86,930 (26.92%)	49,437 (25.67%)
- South	117,440 (36.37%)	61,486 (31.93%)
- West	59,219 (18.34%)	39,522 (20.53%)
Hospital Setting		
- Urban	276,641 (85.68%)	169,438 (88.00%)
- Rural	46,253 (14.32%)	23,115 (12.00%)
Hospital teaching status		
- Non-teaching	182,023 (56.37%)	95,428 (49.56%)
- Teaching	140,872 (43.63%)	97,126 (50.44%)
Hospital Bed Size		
- Small	46,690 (14.46%)	28,212 (14.65%)
- Medium	79,576 (24.64%)	44,228 (22.97%)
- Large	196,629 (60.90%)	120,113 (62.38%)
Surgeon Volume (Cases/year)		
- TKA: 1-17; THA: 1-10	49,080 (15.20%)	30,925 (16.06%)
- TKA: 18-35; THA: 11-21	50,974 (15.79%)	26,599 (13.81%)
- TKA: 36-66; THA: 22-52	47,610 (14.74%)	28,450 (14.78%)
- TKA: ≥67; THA: ≥53	48,962 (15.16%)	28,572 (14.84%)
- Missing	126,269 (39.11%)	78,008 (40.51%)
Hospital Volume (Cases/year)		
- TKA: 1-100; THA: 1-64	83,060 (25.72%)	50,248 (26.10%)
- TKA: 101-197; THA: 65-123	83,791 (25.95%)	47,925 (24.89%)
- TKA: 198-293; THA: 124-224	76,898 (23.82%)	48,628 (25.25%)
- TKA: ≥293; THA: ≥225	79,146 (24.51%)	45,751 (23.76%)
Hospital Ownership		
- Government or Private	190,951 (59.14%)	124,914 (64.87%)
- Public	17,722 (5.49%)	9,005 (4.68%)
- Private Non-profit	65,964 (20.43%)	33,837 (17.57%)
- Private For-profit	29,701 (9.20%)	14,852 (7.71%)
- Private (Unspecified)	18,556 (5.75%)	9,945 (5.16%)
Unadjusted average Length of Stay (LOS)	3.74 (±1.43)	3.90 (±1.43)

Table 2
Associations between Patient-level and Provider-level variables – Total Knee Arthroplasty

	REGION	SETTING	TEACHING	BED SIZE	SURGEON VOLUME	HOSPITAL VOLUME	HOSPITAL OWNERSHIP
Age: Mean (SD)	NE: 67.9 (10.6) MW: 67.5 (10.7) S: 66.9 (10.6) W: 67.8 (10.6) p < 0.0001	Urban: 67.3 (10.7) Rural: 67.6 (10.5) p < 0.0001	Non-teaching: 67.8 (10.5) Teaching: 66.9 (10.7) p < 0.0001	Small: 67.5 (10.5) Medium: 66.9 (10.8) Large: 67.5 (10.6) p < 0.0001	1-17: 67.2 (10.7) 18-35: 67.2 (10.7) 36-66: 67.7 (10.4) ≥ 67: 67.9 (10.5) Missing: 67.2 (10.7) p < 0.0001	1-100: 67.6 (10.7) 101-197: 67.5 (10.7) 198-293: 67.2 (10.6) ≥ 294: 67.1 (10.5) p < 0.0001	Government: 67.4 (10.9) Non-profit: 67.7 (10.6) For-profit: 67.5 (10.3) p = 0.2005
Gender (% female)	NE: 65.37% MW: 64.76% S: 65.12% W: 62.52% p < 0.0001	Urban: 64.51% Rural: 65.09% p = 0.2740	Non-teaching: 64.14% Teaching: 65.18% p = 0.0053	Small: 65.02% Medium: 64.56% Large: 64.50% p = 0.6190	1-17: 64.99% 18-35: 65.33% 36-66: 64.05% ≥ 67: 63.50% Missing: 64.65% p = 0.0183	1-100: 66.31% 101-197: 64.30% 198-293: 64.01% ≥ 294: 63.65% p < 0.0001	Government: 65.95% Non-profit: 63.95% For-profit: 63.54% p = 0.0385
Race (% Black)	NE: 5.74% MW: 5.68% S: 12.06% W: 5.00% p < 0.0001	Urban: 8.78% Rural: 4.66% p < 0.0001	Non-teaching: 5.60% Teaching: 12.20% p < 0.0001	Small: 6.20% Medium: 9.91% Large: 7.99% p < 0.0001	1-17: 10.32% 18-35: 9.22% 36-66: 8.35% ≥ 67: 6.09% Missing: 5.62% p < 0.0001	1-100: 6.79% 101-197: 9.03% 198-293: 7.28% ≥ 294: 7.24% p < 0.0001	Government: 10.29% Non-profit: 6.39% For-profit: 7.47% p < 0.0001
Charlson Score: mean (SD)	NE: 0.33 (0.64) MW: 0.46 (0.73) S: 0.47 (0.73) W: 0.40 (0.70) p < 0.0001	Urban: 0.43 (0.71) Rural: 0.41 (0.71) p = 0.3389	Non-teaching: 0.42 (0.71) Teaching: 0.43 (0.72) p = 0.0054	Small: 0.38 (0.61) Medium: 0.41 (0.63) Large: 0.42 (0.63) p < 0.0001	1-17: 0.42 (0.64) 18-35: 0.40 (0.62) 36-66: 0.41 (0.63) ≥ 67: 0.39 (0.62) Missing: 0.41 (0.63) p = 0.0058	1-100: 0.41 (0.63) 101-197: 0.40 (0.62) 198-293: 0.41 (0.63) ≥ 294: 0.41 (0.63) p = 0.7777	Government: 0.45 (0.71) Non-profit: 0.46 (0.73) For-profit: 0.42 (0.70) p = 0.0098
Income (% <\$35,000)	NE: 17.12% MW: 19.00% S: 33.42% W: 15.28% p < 0.0001	Urban: 18.30% Rural: 44.33% p < 0.0001	Non-teaching: 25.37% Teaching: 17.68% p < 0.0001	Small: 20.00% Medium: 21.16% Large: 22.80% p < 0.0001	1-17: 10.32% 18-35: 9.22% 36-66: 8.35% ≥ 67: 6.09% Missing: 5.62% p < 0.0001	1-100: 7.24% 101-197: 7.28% 198-293: 9.03% ≥ 294: 6.79% p < 0.0001	Government: 29.85% Non-profit: 28.16% For-profit: 26.99% p = 0.0055
Insurance Status (% Medicaid or dual)	NE: 6.33% MW: 3.84% S: 5.70% W: 3.17% p < 0.0001	Urban: 4.38% Rural: 7.67% p < 0.0001	Non-teaching: 4.84% Teaching: 4.87% p = 0.8371	Small: 6.12% Medium: 4.63% Large: 4.64% p < 0.0001	1-17: 9.20% 18-35: 9.76% 36-66: 9.39% ≥ 67: 7.52% Missing: 6.19% p < 0.0001	1-100: 7.61% 101-197: 7.79% 198-293: 8.89% ≥ 294: 7.29% p < 0.0001	Government: 6.91% Non-profit: 4.16% For-profit: 6.12% p < 0.0001

Table 3

Associations between Patient-level and Provider-level variables – Total Hip Arthroplasty

	REGION	SETTING	TEACHING	BED SIZE	SURGEON VOLUME	HOSPITAL VOLUME	HOSPITAL OWNERSHIP
Age: Mean (SD)	NE: 66.4 (13.0) MW: 66.2 (13.0) S: 65.1 (13.8) W: 65.9 (13.1) p < 0.0001	Urban: 65.51 (13.4) Rural: 68.0 (12.5) p < 0.0001	Non-teaching: 67.4 (12.8) Teaching: 64.1 (13.6) p < 0.0001	Small: 64.9 (13.4) Medium: 65.9 (13.2) Large: 66.0 (13.3) p < 0.0001	1-10: 68.0 (13.3) 11-21: 66.7 (12.9) 22-52: 65.3 (13.4) ≥ 53: 64.0 (13.0) Missing: 65.4 (13.4) p < 0.0001	1-64: 67.2 (13.1) 65-123: 66.5 (13.1) 124-224: 65.7 (13.3) ≥ 225: 63.7 (13.4) p < 0.0001	Government: 67.3 (12.9) Non-profit: 67.0 (12.9) For-profit: 66.3 (13.5) p = 0.0054
Gender (% female)	NE: 57.33% MW: 58.48% S: 57.33% W: 57.80% p = 0.2854	Urban: 57.62% Rural: 58.47% p = 0.2689	Non-teaching: 58.65% Teaching: 56.81% p = 0.0002	Small: 58.21% Medium: 58.04% Large: 57.50% p = 0.4951	1-10: 60.22% 11-21: 58.52% 22-52: 58.69% ≥ 53: 55.47% Missing: 56.59% p < 0.0001	1-64: 59.16% 65-123: 58.67% 124-224: 56.91% ≥ 225: 56.00% p < 0.0001	Government: 58.18% Non-profit: 58.47% For-profit: 58.62% p = 0.9540
Race (% Black)	NE: 4.45% MW: 5.49% S: 10.80% W: 4.60% p < 0.0001	Urban: 7.23% Rural: 4.57% p < 0.0001	Non-teaching: 5.05% Teaching: 9.06% p < 0.0001	Small: 4.91% Medium: 7.50% Large: 7.25% p < 0.0001	1-10: 9.76% 11-21: 5.89% 22-52: 7.67% ≥ 53: 5.49% Missing: 5.19% p < 0.0001	1-64: 7.12% 65-123: 6.70% 124-224: 5.18% ≥ 225: 7.38% p < 0.0001	Government: 9.85% Non-profit: 5.76% For-profit: 6.42% p < 0.0001
Charlson Score: mean (SD)	NE: 0.33 (0.70) MW: 0.42 (0.76) S: 0.45 (0.81) W: 0.38 (0.77) p < 0.0001	Urban: 0.40 (0.77) Rural: 0.41 (0.76) p = 0.0503	Non-teaching: 0.42 (0.77) Teaching: 0.39 (0.77) p = 0.0006	Small: 0.32 (0.57) Medium: 0.38 (0.63) Large: 0.38 (0.62) p < 0.0001	1-10: 0.42 (0.65) 11-21: 0.36 (0.60) 22-52: 0.35 (0.60) ≥ 53: 0.34 (0.59) Missing: 0.37 (0.61) p < 0.0001	1-64: 0.39 (0.63) 65-123: 0.38 (0.62) 124-224: 0.36 (0.61) ≥ 225: 0.34 (0.59) p < 0.0001	Government: 0.45 (0.83) Non-profit: 0.43 (0.77) For-profit: 0.42 (0.79) p = 0.2878
Income (% <\$35,000)	NE: 14.17% MW: 18.58% S: 28.63% W: 15.28% p < 0.0001	Urban: 15.20% Rural: 42.08% p < 0.0001	Non-teaching: 22.38% Teaching: 14.49% p < 0.0001	Small: 16.50% Medium: 18.44% Large: 18.82% p < 0.0001	1-10: 9.76% 11-21: 5.89% 22-52: 7.67% ≥ 53: 5.49% Missing: 5.19% p < 0.0001	1-64: 7.12% 65-123: 6.70% 124-224: 5.18% ≥ 225: 7.38% p < 0.0001	Government: 24.27% Non-profit: 24.34% For-profit: 21.51% p = 0.0038
Insurance Status (% Medicaid or dual)	NE: 5.56% MW: 4.06% S: 5.36% W: 3.56% p < 0.0001	Urban: 4.28% Rural: 7.82% p < 0.0001	Non-teaching: 4.56% Teaching: 4.84% p = 0.1852	Small: 6.26% Medium: 4.49% Large: 4.42% p < 0.0001	1-10: 8.85% 11-21: 8.40% 22-52: 8.89% ≥ 53: 5.46% Missing: 6.24% p < 0.0001	1-64: 8.08% 65-123: 7.76% 124-224: 6.56% ≥ 225: 6.47% p < 0.0001	Government: 6.97% Non-profit: 4.27% For-profit: 4.32% p < 0.0001

Table 4
Unadjusted Length of Stay Associated with Patient and Provider Characteristics

Values given are transformed mean LOS (95% CI)		Total Knee Arthroplasty	Total Hip Arthroplasty
<i>Patient Characteristics</i>			
Gender	MALE	3.68 (3.66, 3.70)	3.82 (3.80, 3.84) p < 0.0001
	FEMALE	3.78 (3.76, 3.79)	3.98 (3.96, 3.99)
Age	18-44	3.41 (3.48, 3.63)	3.70 (3.65, 3.75) p < 0.0001
	45-64	3.63 (3.62, 3.65)	3.75 (3.73, 3.77)
	65-84	3.79 (3.78, 3.81)	3.98 (3.96, 4.00)
	85+	4.06 (4.00, 4.13)	4.69 (4.59, 4.79)
Race	WHITE	3.69 (3.67, 3.70)	3.92 (3.90, 3.94) p < 0.0001
	BLACK	3.90 (3.85, 3.95)	4.11 (4.03, 4.18)
	OTHER*	3.89 (2.62, 5.76)	3.94 (2.66, 5.85)
	MISSING	3.77 (2.70, 5.26)	3.84 (2.67, 5.53)
Charlson Score	0	3.65 (3.64, 3.66)	3.80 (3.78, 3.81) p < 0.0001
	1	3.85 (3.83, 3.88)	4.08 (4.04, 4.11)
	2+	4.18 (4.14, 4.23)	4.56 (4.49, 4.64)
Income	\$1-24,999	3.94 (3.87, 4.00)	4.26 (4.16, 4.36) p < 0.0001
	\$25-34,999	3.77 (3.75, 3.80)	3.99 (3.95, 4.02)
	\$35-44,999	3.78 (3.75, 3.80)	3.96 (3.93, 3.98)
	\$45+	3.70 (3.68, 3.71)	3.85 (3.83, 3.87)
Insurance	PRIVATE	3.58 (3.56, 3.60)	3.68 (3.66, 3.70) p < 0.0001
	MEDICARE	3.81 (3.80, 3.82)	4.05 (4.03, 4.07)
	MEDICAID	4.12 (4.03, 4.20)	4.31 (4.20, 4.41)
	OTHER	3.83 (3.78, 3.89)	4.02 (3.91, 4.12)
<i>Provider Characteristics</i>			
Region	Northeast	3.63 (2.53, 5.21)	3.86 (2.68, 5.55) p < 0.0001
	Midwest	3.76 (2.72, 5.19)	3.91 (2.80, 5.48)
	South	3.79 (2.60, 5.51)	4.00 (2.74, 5.82)

Values given are transformed mean LOS (95% CI)	Total Knee Arthroplasty		Total Hip Arthroplasty	
	Mean LOS	95% CI	Mean LOS	95% CI
Setting	West	3.75 (2.61, 5.38)	3.84 (2.64, 5.57)	
	Urban	3.73 (2.62, 5.30)	3.88 (2.70, 5.58)	p < 0.0001
	Rural	3.85 (2.60, 5.69)	4.13 (2.85, 6.00)	
Teaching Status	Non-teaching	3.75 (2.60, 5.40)	3.97 (2.77, 5.69)	p < 0.0001
	Teaching	3.74 (2.64, 5.29)	3.86 (2.67, 5.57)	
Bed size	Small	3.83 (2.73, 5.38)	4.04 (2.90, 5.63)	p < 0.0001
	Medium	3.71 (2.62, 5.25)	3.89 (2.73, 5.54)	
	Large	3.74 (2.59, 5.39)	3.89 (2.67, 5.65)	
Surgeon Volume	TKA: 1-17; THA: 1-10	3.95 (2.48, 5.42)	4.30 (2.77, 5.82)	p < 0.0001
	TKA: 18-35; THA: 11-21	3.80 (2.37, 5.22)	3.96 (2.55, 5.37)	
	TKA: 36-66; THA: 22-52	3.61 (2.20, 5.01)	3.79 (2.41, 5.17)	
	TKA: ≥ 67; THA: ≥ 53	3.45 (2.02, 4.88)	3.50 (2.07, 4.94)	
Hospital Volume	VOLUME MISSING	3.82 (2.71, 5.38)	3.95 (2.79, 5.60)	
	TKA: 1-100; THA: 1-64	3.95 (2.49, 5.40)	4.17 (2.69, 5.64)	p < 0.0001
	TKA: 101-197; THA: 65-123	3.66 (2.21, 5.11)	3.91 (2.47, 5.34)	
	TKA: 198-293; THA: 124-224	3.77 (2.37, 5.16)	3.86 (2.47, 5.24)	
Ownership	TKA: ≥ 294; THA: ≥ 225	3.61 (2.20, 5.02)	3.72 (2.27, 5.16)	
	ALL HOSPITALS	3.74 (2.64, 5.28)	3.88 (2.69, 5.89)	p < 0.0001
	PUBLIC	3.97 (2.72, 5.81)	4.17 (2.85, 6.10)	
	NON-PROFIT	3.73 (2.64, 5.28)	3.88 (2.71, 5.56)	
	FOR-PROFIT	3.69 (2.46, 5.53)	4.02 (2.82, 5.75)	

Other race includes: Hispanic, Native American, Asian or Pacific Islander, or Other

Table 5

Relative Differences to Length of Stay

<i>Patient Factors</i>		Total Knee Arthroplasty		Total Hip Arthroplasty	
Gender	MALE	1.000	--	1.000	--
	FEMALE	1.020	p = 0.000	1.026	p = 0.000
Age	18-59	1.000	--	1.000	--
	60-68	1.020	p = 0.000	1.011	p = 0.036
	68-75	1.014	p = 0.048	1.006	p = 0.560
	75+	1.053	p = 0.000	1.084	p = 0.000
Race	WHITE	1.000	--	1.000	--
	BLACK	1.035	p = 0.000	1.056	p = 0.000
	OTHER*	1.011	p = 0.117	0.988	p = 0.250
	MISSING	1.005	p = 0.628	0.999	p = 0.897
	0	1.000	--	1.000	--
Charlson score	1	1.045	p = 0.000	1.056	p = 0.000
	2+	1.124	p = 0.000	1.174	p = 0.000
	\$1-24,999K	1.011	p = 0.322	1.038	p = 0.008
Income	\$25,000-34,999	1.012	p = 0.012	0.992	p = 0.288
	\$35,000-44,999	1.010	p = 0.013	1.003	p = 0.629
	\$45,000+	1.000	--	1.000	--
	PRIVATE	1.000	--	1.000	--
Insurance	MEDICARE	1.031	p = 0.000	1.027	p = 0.006
	MEDICAID	1.088	p = 0.000	1.103	p = 0.000
	DUAL ENROLL	1.025	p = 0.049	1.078	p = 0.000
	OTHER	1.039	p = 0.000	1.061	p = 0.000
<i>Provider Factors</i>					
Hospital Region	NORTHEAST	1.000	--	1.00	--
	MIDWEST	0.986	p = 0.539	0.964	p = 0.122

<i>Provider Factors</i>						
Setting	SOUTH	1.092	p = 0.003	1.077	p = 0.013	
	WEST	1.037	p = 0.309	0.999	p = 0.978	
Teaching Status	URBAN	1.000	--	1.000	--	
	RURAL	1.021	p = 0.257	1.038	p = 0.040	
Bed Size	NON-TEACHING	1.000	--	1.000	--	
	TEACHING	1.003	p = 0.861	1.012	p = 0.583	
Surgeon Volume (Cases/year)	SMALL	1.000	--	1.000	--	
	MEDIUM	1.004	p = 0.856	1.007	p = 0.733	
Hospital Volume (Cases/year)	LARGE	1.007	p = 0.700	1.013	p = 0.517	
	TKA: 1-17; THA: 1-10	1.108	p = 0.000	1.188	p = 0.000	
Hospital Ownership	TKA: 18-35; THA: 11-21	1.052	p = 0.007	1.073	p = 0.005	
	TKA: 36-66; THA: 22-52	0.977	p = 0.250	1.052	p = 0.038	
Other race includes: Hispanic, Native American, Asian or Pacific Islander, or Other	TKA: ≥ 67; THA: ≥ 53	1.000	--	1.000	--	
	MISSING	1.040	0.446	1.090	p = 0.019	
Hospital Volume (Cases/year)	TKA: 1-100; THA: 1-64	1.113	p = 0.000	1.146	p = 0.001	
	TKA: 101-197; THA: 65-123	0.999	p = 0.982	1.055	p = 0.152	
Hospital Ownership	TKA: 198-293; THA: 124-224	1.031	p = 0.288	1.030	p = 0.368	
	TKA: ≥ 294; THA: ≥ 225	1.000	--	1.000	--	
Other race includes: Hispanic, Native American, Asian or Pacific Islander, or Other	NON-PROFIT	1.000	--	1.000	--	
	PUBLIC	1.023	p = 0.422	1.025	p = 0.390	
Other race includes: Hispanic, Native American, Asian or Pacific Islander, or Other	FOR-PROFIT	1.002	p = 0.923	1.033	p = 0.187	
	PRIVATE (NOT SPECIFIED)	0.961	p = 0.052	0.963	p = 0.047	