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**BACKGROUND:** The use of total joint arthroplasties is increasing worldwide. In this work we aim to elucidate recent trends in demographics and perioperative outcomes of patients undergoing total hip (THA) or total knee arthroplasty (TKA).

**METHODS:** Data from the US Nationwide Inpatient Sample between 1998 and 2008 were gathered for primary THAs and TKAs. Trends in patient age, comorbidity burden, length of hospitalization, frequency of major perioperative complications, and in-hospital mortality were analyzed. In-hospital outcomes were reported as events per 1000 inpatient days to account for changes in length of hospitalization over time. Deyo index, discharge status, and the interaction effect of time and discharge status were included in the adjusted trend analysis for morbidity.

**RESULTS:** Between 1998 and 2008, the average age of patients undergoing TKA and THA decreased by 2 to 3 years (P < 0.001). The average length of stay decreased by approximately 1 day over the time interval studied (P < 0.001). The percentage of patients being discharged home declined from 29.7% to 25.4% after TKA and from 29.3% to 24.2% after THA, in favor of dispositions to long- and short-term care facilities (P < 0.0001). Comorbidity burden as measured by the Deyo comorbidity index increased by 35% and 30% for TKA and THA patients, respectively (P < 0.0001). After TKA, there was an increase in the incidence of the following major complications: pulmonary embolism (coefficient estimate [CE] 0.069; 95% confidence interval [CI], 0.059–0.079; P < 0.0001), sepsis (CE 0.034; 95% CI, 0.014–0.054; P = 0.001), nonmyocardial infarction cardiac complications (CE 0.038; 95% CI, 0.035–0.041; P < 0.0001), and pneumonia (CE 0.039; 95% CI, 0.031–0.047; P < 0.0001). After THA, there was an increase in the incidence of the following major complications: pulmonary embolism (CE 0.031; 95% CI, 0.012–0.049; P = 0.001), sepsis (CE 0.060; 95% CI, 0.039–0.081; P < 0.0001), nonmyocardial infarction cardiac complications (CE 0.040; 95% CI, 0.036–0.043; P < 0.0001), and pneumonia (CE 0.039; 95% CI, 0.029–0.048). In-hospital mortality declined after both TKA (CE −0.059; 95% CI, −0.077 to −0.040; P < 0.0001) and THA (CE −0.068; 95% CI, −0.086 to −0.051; P < 0.0001).

**CONCLUSION:** Between 1998 and 2008, trends show increases in several major in-hospital complications after TKA and THA, including pulmonary embolism, sepsis, nonmyocardial infarction cardiac complications, and pneumonia. Despite the increase in complications, declining in-hospital mortality was noted over this period. (Anesth Analg 2012;115:321–7)

Data evaluating recent nationally representative trends in outcomes after total joint arthroplasty are lacking. Such nationally representative data have the potential to facilitate the creation of benchmarks against which institutions can compare their outcomes and ultimately identify targets for improvement.

Mortality and other major perioperative complications after total hip arthroplasty (THA) and total knee arthroplasty (TKA) are rare.1–2 Reported mortality rates have varied over the years with more recent reports falling between 0.16% and 1.0%.3–5 Prevalently reported in-hospital mortality data from the 1990s and the early part of this decade are difficult to interpret because changes in the average length of stay clearly impact on the capture timeframe, thus skewing interpretations. In our previous studies we demonstrated that the length of stay for primary total knee replacement diminished from 8.4 days in the period between 1990 to 1994 to 4.2 days in the period 2000 to 2004.6 An analysis that controls for number of admitting days is paramount. With a longer hospital stay, the likelihood of capturing a procedure-related complication increases.7

In this study we analyzed trends in major morbidity and mortality after primary THA and TKA using data...
from the largest all-payer database in the United States while accounting for changes in length of hospital stay, comorbidity burden, and discharge disposition. Specifically, we examined changes in the rates of the following major sources of perioperative morbidity after total hip and total knee replacement surgery: pulmonary and cardiac complications, sepsis, pneumonia, shock and cardiac arrest, and mortality.

We hypothesized that the adjusted rates for major morbidity and mortality decreased over the decade of our study.

METHODS
Data Source
Nationwide Inpatient Sample (NIS) data files were commercially obtained from the Hospital Cost and Utilization Project and analyzed for this study. The NIS is the largest all-payer inpatient discharge database in the United States and is sponsored by the Agency for Healthcare Research and Quality. NIS data are compiled from approximately 1000 hospitals and represent 20% of all hospital admissions nationwide. A weighting procedure is provided by the NIS to allow for representative national estimates from the stratified data sample. Detailed information on the NIS design can be accessed electronically. This project was exempt from review by the IRB because data used in this study are sufficiently deidentified.

Selection of Study Sample and Statistical Methods
Our study sample consists of all data in NIS for each year between 1998 and 2008. Admissions for lower-extremity joint arthroplasty were identified using International Classification of Diseases (9th revision, Clinical Modification; ICD-9-CM) codes for primary unilateral total joint arthroplasty were identified using Internationally. We selected data from inpatient admissions occurring between 1998 and 2008. Hip replacements were classified as THAs (ICD-9-CM 81.51) and TKAs (ICD-9-CM 81.54) replacement.

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RESULTS
According to nationally representative weighted NIS data, 2290,751 THAs and 4439,784 TKAs were performed in the United States between 1998 and 2008. This estimate was calculated from a stratified sample of 469,013 THA and 910,399 TKA admissions recorded in the NIS dataset. The number of procedures performed per year increased by 144% for TKAs and 79% for THAs between 1998 and 2008. Most recently, more than twice as many primary TKAs as THAs were performed, approaching an estimated 616,600 and 277,400 procedures in 2008, respectively (Fig. 1).

From the univariate analysis, the average age decreased for patients undergoing THA and TKA procedures by approximately 2.1 years (CE 0.173; 95% CI, 0.168–0.178; P < 0.0001) and 2.7 years (CE 0.232; 95% CI, 0.227–0.236; P < 0.0001), respectively (Fig. 2). In 2008, the most recent year examined, THA recipients were on average 1 year younger than were their TKA counterparts. During the decade studied, comorbidity burden increased among both TKA patients (CE 0.019; 95% CI, 0.017–0.021; P < 0.0001) and THA patients (CE 0.013; 95% CI, 0.012–0.014; P < 0.0001) (Fig. 3). Patients admitted for a TKA carried, on
average, a higher comorbidity burden than did THA admissions at any given time point.

The average length of stay decreased by approximately 1 day from 1998 to 2008, and was approximately 3.6 days for THA recipients (CE \(-0.106 ; 95\% \text{ CI}, -0.109 \text{ to } -0.103; P < 0.001\)) and 3.4 days for TKA recipients (CE \(-0.099 ; 95\% \text{ CI}, -0.101 \text{ to } -0.098; P < 0.001\)) in 2008 (Fig. 4). At the same time a decrease in the percentage of routine discharges was seen after both THA (CE \(-0.032 ; 95\% \text{ CI}, -0.034 \text{ to } -0.03; P < 0.001\)) and TKA (CE \(-0.028 ; 95\% \text{ CI}, -0.029 \text{ to } -0.026; P < 0.001\)) (Fig. 5). In the adjusted analysis, higher comorbidity index and longer hospital stay were positively associated with nonroutine discharge (Table 1). The trends for declining routine discharge over time remained significant after adjusting for Deyo index and length of stay (Table 1).

In-hospital mortality rates decreased (\(P < 0.0001\)) by 56% for THA (from 0.43% in 1998) and 54% for TKA procedures (from 0.2% in 1998) to reach national averages of 0.19% and 0.09% in 2008, respectively. When adjusting for changes in length of hospital stay, the decreases represented a 44% decrease and a 41% decrease in the mortality per 1000 inpatient days for THA and TKA procedures, respectively (Fig. 6, Table 2). Analysis adjusted for comorbidity burden revealed that higher Deyo index increased the risk for mortality after both THA and TKA while controlling for time (Table 2).
After TKA and THA, there were increases in the incidence of the following major complications: PE, sepsis, non-MI cardiac complications, and pneumonia (Figs. 7 and 8, Table 2). Comparatively, the rate of increase for PE was slower and the trend less pronounced for THA admissions than for TKA admissions (Fig. 8). In the adjusted analysis, higher Deyo index was associated with increased rates of all of the examined postoperative complications except for shock and PE in TKA patients (Table 2). The upward trends described above maintained significance after controlling for comorbidity burden and discharge status (Table 2).

The incidence of postoperative MI declined slightly in TKA patients and increased slightly in THA patients. Shock/cardiac arrest declined after TKA but was unchanged after THA. These trends maintained significance after adjusting for comorbidity burden and discharge status except for the increase in acute MI after THA (Table 2).

**DISCUSSION**

Using the NIS, the largest publicly available nationally representative database of hospital admissions, we have described trends in perioperative morbidity and mortality after lower-extremity total joint arthroplasty between 1998 and 2008. Over
this time period, there have been increases in the number of TKAs and THAs performed each year, the comorbidity burden of patients presenting for surgery, and the rates of several potentially life-threatening perioperative complications. Simultaneously, in-hospital mortality and the length of hospital stay have declined for this patient population.
Between 1998 and 2008, length of hospital stay for TKA and THA patients declined by approximately 1 day (from nearly 4.5 to 3.5 days). Over this time period, progressively more patients were discharged to a care facility other than to their customary residence. Although higher comorbidity burden and increased length of stay were associated with nonroutine discharge, the trend of declining rates of routine discharge remained significant after controlling for these factors. Although the majority of major complications are expected to occur during the current average 3.5-day hospital stay after TKA or THA, a significant number of events may occur after discharge.12,13 Even with a decline in length of hospital stay, however, there was a notable increase in the rates of PE, pneumonia, sepsis, and non-MI cardiac complications after TKA between 1998 and 2008. THA patients had increased rates of all of the aforementioned complications, though the increases were more subtle than were those seen with TKA.

The data in this paper present a clear and significant trend of increasing rates of the diagnosis of PE after TKA between 1998 and 2008. These in-hospital rates of thromboembolism may be underestimates of the overall burden because the Global Orthopaedic Registry estimates that postoperative thromboembolism occurs after hospital discharge in >50% of TKA patients and 75% of THA patients.13 This finding is of concern because venous thromboembolism has been associated with increased mortality, increased rates of rehospitalization in 1 year, and significantly higher health care costs after TKA and THA.14–16

The increase in the diagnosis of PE remains significant after controlling for increases in comorbidity burden, and the reason for the increase cannot be determined by the data available from the NIS. However, in several other studies, adoption of computer tomography pulmonary angiography in the detection of PE since 1998 has been shown to have led to an overall increase in the number of events being recorded and treated.17–20 Parvizi et al. studied an apparent increase in the incidence of pulmonary embolus after joint arthroplasty at their institution.21 The incidence of pulmonary embolus increased from 0.21% when ventilation/perfusion scan was the modality of choice, to 0.98% during the time spiral computed tomography was used, to 1.72% in recent years when multidetector computed tomography was used. Despite the apparent increase in PE rate, they observed no change in mortality. It is possible that part of the increasing rate of PE recorded in this study may also be attributable to the adoption of enhanced detection techniques over time. It is paramount to determine whether there has been a true increase in the prevalence of clinically significant PEs or whether rates are being artificially elevated because of an increase in the use of highly sensitive spiral computer tomographic angiography.

Despite increases in many perioperative complications associated with TKA and THA, rates of MI declined for TKA patients. Rates of acute MI after THA increased slightly over the decade examined, but unlike other complications, this increase disappeared when outcome was controlled for comorbidity index. In-hospital mortality rates per 1000 inpatient days decreased by >40% between 1998 and 2008. By 2008, the overall in-hospital mortality rate was down to 0.19% for THA and 0.09% for TKA. These low mortality rates are consistent with the stable and declining rates of postoperative shock/cardiopulmonary arrest seen after THA and TKA, respectively. These findings suggest that despite increasing levels of comorbidities and higher rates of many perioperative complications, improvements in perioperative management have reduced catastrophic outcomes, including cardiac arrest and in-hospital mortality. It is worth noting, however, that reductions in hospital length of stay have likely transferred some of the perioperative mortality burden to intermediate-care facilities.

Our study is limited by several factors inherent to retrospective analysis of large administrative databases. Conclusions should be limited to the acute perioperative setting as events occurring postdischarge, and data on readmissions are not included. Details of patient management, discharge criteria, thromboprophylaxis, and rehabilitation protocols are not available in the NIS and therefore cannot be correlated with outcomes. Data entry may be subject to an element of coding or reporting bias; however, reporting should not vary substantially over time within the database. Over the years examined, patient data were likely to have been exposed to the same bias within the same data collection construct; thus trend analysis is less likely to be affected by such bias.

In conclusion, the number of THAs and TKAs performed in the United States is rapidly increasing in an increasingly comorbidity-ridden population. This higher comorbidity burden is associated with higher risk of perioperative morbidity and mortality after THA and TKA. As hospital stays become shorter, the burden of care for these patients is shifting to the intermediate care facilities to which they are being discharged with increasing frequency. The impact of these changes on the overall use of health care resources remains to be determined. Fortunately, declining rates of shock/cardiac arrest and mortality suggest that current in-hospital perioperative management of THA and TKA patients has reduced catastrophic outcomes.

**DISCLOSURES**

**Name:** Meghan Kirksey, MD, PhD.

**Contribution:** This author helped analyze the data and write the manuscript.

**Attestation:** Meghan Kirksey has seen the original study data, reviewed the analysis of the data, and approved the final manuscript.

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**Contribution:** This author helped conduct the study and analyze the data.

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REFERENCES