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Epidemiology and risk factors for perioperative mortality after total hip and knee arthroplasty

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Abstract

Purpose—The perioperative mortality of total knee and hip arthroplasties (TKA, THA) remains a major concern among health care providers and their patients. The increase in utilization of TKA and THA makes it imperative to be aware of factors that are associated with this unfortunate event.

Methods—Therefore we analyzed the Nationwide Inpatient Sample data from 1998–2008 and compared admissions with perioperative mortality to those that survived their hospitalization.

Results—An estimated total of 4,438,213 TKA and 2,182,121 THA procedures were performed in the United States between 1998 and 2008. The average mortality rate for TKA was 0.13% and 0.18% for THA, or 0.34 and 0.44 events per 1000 inpatient days, respectively. Independent risk factors for in-hospital mortality were advanced age, male gender, ethnic minority background, emergency admission as well as a number of comorbidities and complications. Furthermore, we demonstrated that the timing of death occurred earlier after TKA when compared to THA, with 50% of fatalities occurring by day 4 versus day 6 of the hospitalization, respectively.

Conclusion—This study provides nationally representative information on risk factors for and timing of perioperative mortality after TKA and THA. Our data can be used to assess the risk for perioperative mortality and to develop targeted intervention to decrease such risk.

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IRB: As the data used in this study are sufficiently de-identified this project was exempt from review by the institutional review board.

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Keywords

total knee arthroplasty; total hip arthroplasty; joint replacement; complications; mortality

Introduction

Total hip and knee arthroplasties (THA, TKA) are highly effective procedures and the utilization of total joint replacements performed in the United States is expected to increase dramatically over the next decade.¹⁻⁴ Total joint replacements of the lower extremity are considered relatively safe, however, the outcome of mortality remains a major concern amongst clinicians and their patients. Although previous studies have suggested a decrease in mortality after TKA and THA over time, the dramatic increase in demand is likely to assure a significant number of perioperative fatal events.^{5,6} Therefore, the increase in utilization of these procedures performed in an elderly population with significant comorbidity burden makes it imperative that perioperative clinicians be aware of factors that are associated with this unfortunate outcome. Perioperative mortality after TKA and THA, in general, is difficult to study due to the relatively low overall incidence, thus diminishing the applicability and power of single institutional data and their ability to provide information beyond the computation of mortality rates. To overcome this limitation, large, nationally representative databases provide an alternative to elucidate issues surrounding the subject of in-hospital mortality.

However, studies analyzing such data remain rare and are limited by a number of factors including the inclusion of information based on pooled THA and TKA data collected primarily in the 1990ies⁶. Utilizing information from the Nationwide Inpatient Sample (NIS), the largest all-payer database in the US, that is based on a nationally representative sample of 20% of all hospitalizations, and by employing more recent data from 1998–2008, we sought to characterize factors surrounding the outcome of perioperative mortality after primary TKA and THA. Furthermore, we sought to determine risk factors for such outcome and identify the timing of fatal events. We hypothesized: 1) that patients of increased age and with increased comorbid burden would have higher rates and risk for perioperative in-hospital mortality; 2) that patients suffering from perioperative complications would be at risk for in-hospital mortality, and 3) that the majority of in-hospital fatal events would occur early following surgery.

Materials and Methods

Data Source

NIS data files were analyzed for this study. The NIS is sponsored by the Agency for Healthcare Research and Quality (AHRQ) and represents the largest all payer inpatient discharge database in the United States. Information on the NIS can be accessed on-line at www.hcup-us.ahrq.gov/nisoverview.jsp. Data used in this study are sufficiently de-identified and thus this project was exempt from review by the institutional review board.

Selection of Study Sample and Statistical Methods

The study sample consists of all data in NIS for each year between 1998 and 2008. Admissions during which a primary lower extremity joint arthroplasty was performed were identified using International Classification of Diseases- 9th revision-Clinical Modification (ICD-9-CM) codes for primary hip (81.51) and knee (81.54) replacement. All hip fractures were excluded from analysis. Admissions with a fatal outcome were identified and compared to those in which patients were discharged alive. Patient and healthcare system related characteristics were analyzed. Patient demographics included age, gender, race

(White, Black, Hispanic, Other), and admission type (emergent, elective, urgent and others). Healthcare system related parameters included; hospital size (small, medium, large), geographic location (rural, urban), and teaching status (teaching, non-teaching). Definitions of the variables were adopted from HCUP NIS and are available online at <http://www.hcup-us.ahrq.gov/db/nation/nis/nisdde>. The prevalence of various comorbidities was compared between groups utilizing the Clinical Classifications Software for Services and Procedures (CCSSP). This tool is provided by the AHRQ for the definitions of various disease states and is modeled after the Elixhauser method.⁷ Additionally, in order to account for overall comorbidity burden, the average Deyo comorbidity index was calculated.^{8,9} The timing of in-hospital death was also computed for both THA and TKA procedures. Data were analyzed by time periods (1998/1999, 2000/2001, 2002/2003, 2004/2005, 2006–2008) in order to account for temporal trends in practice.

For each group, the proportions of patients suffering from major complications were computed by identifying cases that had ICD-9-CM diagnosis codes listed, which were consistent with modified definitions provided in the Complication Screening Package designed for use with administrative data.¹⁰ Complications analyzed included: postoperative cerebral infarction, pulmonary compromise, sepsis, acute myocardial infarction, cardiac complications (except myocardial infarction), pneumonia, and pulmonary embolism.

Weighted means and percentages were shown for continuous and categorical variables. Weighted numbers and odds ratios for each variable/event between mortalities and non-mortalities were presented in separate tables in the appendix (see Appendix Tables 1–3).

Approximately one third of entries in the race category were not available and were treated as a separate group (i.e. missing race).

All statistical analyses were performed using SAS version 9.2 (SAS Institute, Cary, NC). To facilitate analysis of data collected in a complex survey design and to obtain consistent estimates of mean and variance parameters while taking into account the complex survey data setting, SAS procedures SURVEYMEANS, SURVEYFREQ, SURVEYREG and SURVEYLOGISTIC were utilized for descriptive analyses and final modeling efforts. P-values and 95% confidence intervals (CI) as a measure of effect size are reported. Bonferroni correction to account for multiple comparisons was applied where appropriate.

For building a parsimonious model with strong predictive covariates only, we took the following steps:¹⁰ First, clinical judgment and significance at a p-value at the 15% level in the univariate analysis were used to choose variables for the process of multivariable modeling. This cutoff was chosen as it has been suggested that using higher significance thresholds may reduce selection bias.¹¹ Second, further variable selection and internal validation of the predictive performance of the model was achieved through a two-step, nonparametric bootstrapping process.¹² In the bootstrap procedure, the original set of data of size N becomes a parent population from which the whole samples are randomly drawn with replacement. In the first step of internal validation the bootstrapping technique was used for variable selection. One hundred bootstrap samples were created, and a stepwise procedure was applied to each sample utilizing a forward selection method (with a selection entry level = 0.20) by using the LOGISTIC procedure. From this analysis, we calculated the percentage of samples for which each variable was included in the model from the 100 samples. For variables which failed the 80% cut-off in the model from the 100 samples, if the frequency of pair wise combinations included in the model from the 100 samples was greater than 90%, we included the one with the largest frequency in the final model. The final model was processed one more time utilizing the SURVEYLOGISTIC procedure instead of the LOGISTIC procedure to be able to obtain appropriate estimates of the

variance for the weighted survey data. This step was necessary, because the SURVEYLOGISTIC does not allow for a forward selection procedure. This methodology has previously been described by Hosmer et al. as appropriate.¹⁰ Interactions between variables were also considered in the analysis. In addition, the c-statistic (also referred to as the Area Under the Receiver Operating Characteristic curve) is used to measure how well the model discriminates between observed data at different levels of the outcome. A c-statistic value above 0.7 is considered indicative of acceptable discrimination.

Results

Between 1998 and 2008 a total of 4,438,213 TKA and 2,182,121 THA procedures were performed in the United States. The unadjusted demographics of patients undergoing TKA and THA expressed as percentages are depicted in table 1. The in-hospital mortality for TKA was 0.13% and 0.18% for THA, or 0.34 and 0.44 events per 1000 inpatient days, respectively. Furthermore, table 1 shows patient and health care system related demographics by procedure type and vital status. Patients who had a fatal outcome were on average older and had higher overall comorbidity burdens than those who left the hospital alive after TKA and THA, respectively.

Male patients were over proportionately affected by mortality after either procedure as were those admitted emergently. Minority race other than Hispanic or Black was associated with higher rates of mortality. Large hospitals were associated with slightly higher mortality rates for TKA but not THA admissions. The ratio of survivors to mortalities who underwent THA and TKA in each time period increased over time, consistent with improvements in mortality outcomes.

The unadjusted prevalence of almost all studied comorbidities was higher amongst mortalities compared to non-mortalities (Table 2). The presence of all studied complications was significantly higher among mortalities than survivors (Table 3). Absolute numbers by vital status and unadjusted odds ratios for all variables are provided in the appendix (appendix Table 1).

Median hospital charges were higher for fatalities than live discharges after TKA and THA (\$19,084 versus \$12,378 and \$22,064 versus \$13,241, respectively ($P<0.0001$)). Average length of hospitalization was 8.2 and 10.3 days for fatalities after TKA and THA and 3.9 and 4.0 days for non-fatalities respectively ($P<0.0001$).

Fatal events occurred sooner for TKA (Figure 1) compared to THA (Figure 2), with 50% of fatalities taking place by day 4 and 6 of the patients' hospitalization, respectively. In the multivariate regression, independent risk factors for in-hospital mortality were advanced age, male gender, ethnic minority background, emergency admission as well as a number of comorbidities, especially the presence of congestive heart failure and metastatic cancer. The risk of a fatal event decreased by 54% over time (Table 4). Postoperative complications all independently increased the odds for a fatal outcome (Table 5). The c-statistics for either model were 0.75 and 0.87, respectively.

Discussion

In this study, we analyzed nationally representative data collected between 1998 to 2008 and compared characteristics of admissions with in-hospital mortality to those without such outcome after TKA or THA. The average perioperative mortality for primary TKA was 0.13% (0.34 events per 1000 in-patient days), whereas that of primary THA was 0.18% (0.44 events per 1000 in-patient days), respectively. Independent risk factors for in-hospital mortality were advanced age, male gender, ethnical minority background, emergency

admission as well as a number of comorbidities and complications. Mortality risk declined over time. Furthermore, we demonstrated that the timing of death occurred within 6 days of surgery in the majority of cases and earlier after TKA when compared to THA. Less than 5% of mortalities occurred on the day of surgery.

The average age of patients who died during their hospitalization was significantly higher for TKA (67.7 vs. 73.7, $p<.0001$) as well as for THA (65.3 vs. 74.9, $p<.0001$). The correlation of increased mortality rates and advanced patient age has been shown by several other authors.^{5, 13} The fact that age remains an independent risk factor for mortality even after adjusting for comorbidity burden and other variables, suggests that age is inherently associated with such risk. Our study therefore reaffirms the need to focus on the geriatric population in particular when attempting to introduce interventions to lower the risk for death and when counseling patients about risks of THA and TKA.

In the present study we demonstrate that male gender is a risk factor for perioperative mortality after TKA. This finding is in concordance with results previously reported in the in-hospital arthroplasty population.^{5, 14} While studies suggest that male gender is also associated with an increased risk of mortality within thirty days after elective hip arthroplasty,¹³ this finding could not be confirmed in our in-hospital THA population. This dissimilarity may be attributable to the fact that the analyzed patient population by the latter authors showed a higher comorbidity rate among men, thus highlighting the limitations of institutional data and their inability to provide sufficient power for adequate analysis.

We were able to find significant differences in the rates and risk for a fatal event among members of different racial groups undergoing TKA. Specifically, non-Hispanic, non-Black minorities were at increased risk for perioperative mortality compared to the Caucasian population. The impact of race on outcomes however remains controversial. Mahomed et al. reported on increased risk of mortality of African-Americans following TKA and THA.^{15, 16} However, findings surrounding race as a risk factor have not always been conclusive.^{17, 18} Our analysis indicates increased rates of mortality among racial minorities undergoing TKA. As disparities in outcomes among different racial groups have been reported throughout the medical literature, this issue merits further investigations in order to identify reasons for and eliminate differences in perioperative mortality rates associated with total joint replacement of the lower extremity.

Emergently admitted patients were at increased risk a fatal event during their hospitalization compared with those who were scheduled electively. While no causal relationships can be established from our data, it is feasible that emergent cases do present with less time for optimization of potential medical problems. In this context, it has been previously shown that THA for hip fractures is associated with increased mortality rates.¹⁹ It must be noted however, that hip fractures were excluded from our analysis.

Larger hospitals had higher rates of perioperative mortality after TKA, which reflect the fact that they may be better equipped to take care of more difficult operations which may be associated with higher perioperative mortality. Although establishing causalities was beyond the scope of our study, this trend has been previously described by Memtsoudis et al.⁵ It must be mentioned however, that unlike hospital size, higher procedure volume of total joint replacements is associated with lower risk of mortality and readmission.²⁰ In addition, it is noteworthy that recent literature suggests that factors other than volume, including standardization of care, may be associated with improved outcomes.²⁰

In the present study we were able to find certain conditions which were associated with an increased perioperative mortality following TKA and THA. The conditions associated with the greatest increase were: congestive heart failure, metastatic cancer, renal disease and

coagulopathy. Similar conditions associated with the greatest risk for mortality rate have been described by other authors.^{21, 22} Our data suggests that special attention in the preoperative evaluation and perioperative management should be directed towards patients with any of the mentioned conditions. It will have to be determined if any future perioperative adjustments can impact on the increased risk of adverse outcome among this particular patient population.

All perioperative complications were associated with an increased risk of in-hospital death after TKA and THA. Pulmonary complications and cerebrovascular events were the most significant factors increasing the risk for mortality. Pulmonary vascular comorbidities such as pulmonary hypertension or complications such as thromboembolism have been shown to increase mortality after total joint replacement dramatically.^{23, 24} Pulmonary embolism is a known risk factor and extensive research efforts have targeted this entity,^{24–26} while other complications have been less well addressed in such a manner. However, given the propensity for increasing mortality risk and the significant incidence, more attention should focus in combating non-thromboembolic complications in this patient population.

Our data show that less than 5% of all total joint arthroplasty patient deaths occur on the day of admission, but most die within the first 4–6 days following surgery. Patients undergoing TKA succumb earlier compared to patients undergoing THR. During the post-operative period spanning days 3 to 8 the mortality of patients after TKA was on average approximately 15% higher than that for THA patients. The reasons for this disparity have to remain speculative and may be related to differences in the pathophysiology associated with each procedure. The fact that many acute life threatening complications which may be lethal were more frequent in the TKA versus the THA group may also contribute to this finding (Table 3). In general, however, these findings should be contemplated in the context of the current trend to even shorter hospital stays and fast track approaches. When studying the timing of life-threatening complications after total joint arthroplasty, Parvizi et al. noted that 90% occurred within the first 4 days postoperatively and predominantly in those that did not have any identifiable risk factors for such an event.²⁷

When comparing procedure types, TKA was associated with decreased adjusted odds of a fatal outcome compared to THA. However, this difference was not significant after further adjustment for multiple comparisons. Nevertheless, arguments have been made that the propensity for morbidity and mortality after total joint arthroplasty may be related to the overall load of embolization of cement, fat and bone marrow material during the reaming and implantation process during surgery.²⁸ Indeed, hip arthroplasties require the invasion of intramedullary structures, i.e. the femoral canal to a far greater extend than knee replacements do.

Our study is limited by factors inherent to the analysis of the NIS. Our findings must be interpreted accordingly. Aside from the retrospective nature of our study, the NIS is missing detailed clinical information. The NIS only contains in-patient information and hence the complications after discharge cannot be displayed. Therefore, we assume that the mortality rate associated with TKA and THA is likely higher than captured by in-hospital data alone. Interpretation of results regarding length of stay and cost has to consider that in-hospital mortalities are compared to discharged patients, whose follow up is incomplete. Further, it has to be considered that the population characteristics change with progressive length of stay, i.e. patient acuity likely increases with longer length of hospitalization. Indeed, in a separate analysis we found that overall patient comorbid burden and average age is increased when looking at the cohort of patients still hospitalized one week after surgery compared to the patient group at day 1 of the hospitalization. However, this observation may further be corrupted by the possibility, that some sicker patients may be discharged early on

after surgery to skilled nursing facilities thus making assessment of this variable even more difficult.

Unlike the timing of mortality, the temporal relation of complications to surgery cannot be assessed with our data set. Thus, it is impossible to assess the temporal association of complications to the fatal event.

The potential for coding bias or reporting has to be contemplated. Certainly, in the ICD-9-CM coding system there is a large number of alternative codes for the same diagnosis. However, it is unlikely that this bias would affect the comparative analysis, because both patient subgroups (survivors versus mortalities) are exposed equally within this database construct. In addition, although we used a standard and widely used validated approach when defining comorbidities in this analysis, it must be mentioned that one cannot with certainty determine if a disease was present on admission or developed during a patient's hospitalization.²⁹

Additional limitations of administrative databases can be explained by the fact that they are not designed primarily with clinical research in mind. As mentioned previously, the absence of access to variables detailing clinically important perioperative factors such as blood loss and type of anesthetic used, poses therefore significant limitations. No causal relationships can be established with such data and reasons for certain findings have to remain speculative.

Further, we would like to point out that the limitations mentioned here are not unique to the NIS construct. Other commonly used national databases may pose additional shortcomings. As such, data collected on all Medicare patients are limited by the fact that they exclude individuals who do not meet eligibility criteria, i.e. age requirement. The National Hospital Discharge Survey has the disadvantage of collecting representative data based on a much smaller sample, i.e. 1% of all annual hospitalizations in the United States versus 20% in the NIS.

Our study was able to elucidate patient and health care related variables surrounding in-hospital mortality after THA and TKA. Independent risk factors for this outcome included: advanced age, male gender, non-Hispanic, non-Black minority race, and emergency admission. Among comorbidities with the highest independent risk for perioperative mortality were: congestive heart failure, metastatic cancer, and renal disease. Postoperative complications further increased the risk for a fatal outcome after THA and TKA. Our data can be used in order to inform physicians and their patients of the risk of mortality surrounding these very common surgical procedures and incorporated in the consent process. A discussion of risks and benefits seems prudent especially in those with multiple risk factors for mortality. Researchers and administrators may use these results for the generation of hypotheses for studies targeted to study perioperative in-hospital mortality and appropriate allocation of resource to care for high risk patients.

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Appendix

Table 1

Shown are the unadjusted patient demographics and hospital details of total hip (THA) and knee arthroplasty (TKA) recipients. The numbers are weighted and represent nationally representative estimates.

Demographics						
	Primary TKA			Primary THA		
Group	Alive	Died	OR (95% CI)	Alive	Died	OR (95% CI)
Age groups						
0–44	88247	38	0.79 (0.39, 1.61)	148142	87	0.86 (0.52, 1.41)
45–64	1603953	876	NA *	789482	543	NA
65–74	1543616	1749	2.07 (1.73, 2.48)	636345	868	1.98 (1.56, 2.52)
>75	1174118	3104	4.84 (4.10, 5.71)	594345	2364	5.78 (4.69, 7.11)
Gender						
Male	1589779	2953	NA	935632	1860	NA
Female	2812625	2815	0.54 (0.48, 0.60)	1228326	2003	0.82 (0.71, 0.94)
Race						
White	2724538	3669	NA	1371121	2454	NA
Black	215353	325	1.12 (0.87, 1.44)	98646	229	1.30 (0.96, 1.75)
Hispanic	154022	189	0.91 (0.67, 1.26)	46350	71	0.86 (0.51, 1.44)
Other	103724	219	1.57 (1.16, 2.11)	43047	123	1.60 (1.07, 2.38)
Missing	1215636	1366	0.84 (0.73, 0.96)	611854	986	0.90 (0.76, 1.06)
Admission Type						
Emergent	45972	188	2.70 (1.85, 3.94)	35416	461	4.23 (3.12, 5.73)
Elective	3676990	4650	0.83 (0.67, 1.03)	1777342	2656	0.49 (0.38, 0.62)
Urgent+Other	285204	434	NA	125347	386	NA
Hospital Size						
Small	638409	686	NA	307155	515	NA
Medium	1123482	1471	1.22 (1.00, 1.48)	530916	889	1.00 (0.79, 1.27)
Large	2648184	3602	1.27 (1.06, 1.51)	1331739	2458	1.10 (0.89, 1.36)

Demographics						
	Primary TKA			Primary THA		
Group	Alive	Died	OR (95% CI)	Alive	Died	OR (95% CI)
Hospital Location						
Urban	3803347	4925	NA	1918435	3357	NA
Rural	606728	833	1.06 (0.90, 1.25)	251375	506	1.15 (0.93, 1.42)
Hospital Teaching Status						
Teaching	1852035	2463	NA	1039790	1831	NA
Non-teaching	2558040	3295	0.97 (0.86, 1.09)	1130020	2032	1.02 (0.89, 1.18)
Time Period						
1998–1999	513950	983	NA	291364	684	NA
2000–2001	594881	986	0.87 (0.71, 1.06)	331288	717	0.92 (0.73, 1.16)
2002–2003	714630	1112	0.81 (0.67, 0.99)	378718	768	0.86 (0.69, 1.09)
2003–2005	928190	1146	0.65 (0.53, 0.78)	443582	732	0.70 (0.56, 0.89)
2006–2008	1661622	1540	0.48 (0.41, 0.58)	726066	962	0.56 (0.45, 0.70)

* NA=not applicable for the reference group

Table 2

List of Comorbidities/Complications of patients undergoing total knee (TKA) and hip arthroplasty (THA). Unadjusted data are shown and numbers are based on weighted estimates.

Comorbidities							
		TKA			THA		
Comorbidities		Alive (n)	Died (n)	OR (95% CI)	Alive (n)	Died (n)	OR (95% CI)
Alcohol Abuse	Yes	23438	63	2.07 (1.20, 3.58)	25557	80	1.79 (1.10, 2.90)
	No	4389836	5705	NA *	2145461	3782	NA
Congestive Heart Failure	Yes	124076	1359	10.66 (9.30, 12.20)	56939	958	12.24 (10.40, 14.41)
	No (NA)	4289198	4409	NA	2114079	2905	NA
Chronic Lung Disease	Yes	548493	1113	1.69 (1.46, 1.95)	266900	867	2.07 (1.75, 2.44)
	No	3864782	4655	NA	1904118	2996	NA
Coagulopathy	Yes	49408	354	5.78 (4.56, 7.33)	26634	386	8.95 (7.06, 11.33)
	No	4363867	5413	NA	2144384	3476	NA
Uncomplicated Diabetes Mellitus	Yes	735291	900	0.93 (0.79, 1.08)	231346	422	1.03 (0.82, 1.29)
	No	3677984	4867	NA	1939671	3441	NA
Complicated Diabetes Mellitus	Yes	51219	135	2.03 (1.40, 2.96)	16332	69	2.41 (1.42, 4.09)
	No	4362056	5633	NA	2154686	3793	NA
Liver Disease	Yes	24132	58	1.84 (1.04, 3.25)	15816	94	3.40 (2.15, 5.38)
	No	4389142	5710	NA	2155202	3769	NA
Fluid and Electrolyte Disturbances	Yes	273955	1562	5.61 (4.94, 6.39)	133081	1333	8.07 (6.96, 9.36)
	No	4139319	4205	NA	2037937	2530	NA
Cancer	Yes	62683	158	1.96 (1.37, 2.81)	46603	348	4.51 (3.52, 5.79)

Comorbidities							
		TKA			THA		
Comorbidities		Alive (n)	Died (n)	OR (95% CI)	Alive (n)	Died (n)	OR (95% CI)
	No	4350591	5609	NA	2124414	3515	NA
Metastatic Cancer	Yes	3291	35	8.12 (3.84, 17.17)	7322	179	14.37 (10.18, 20.28)
	No	4409984	5733	NA	2163695	3684	NA
Neurologic Disorders	Yes	106571	386	2.90 (2.30, 3.64)	47796	251	3.09 (2.32, 4.11)
	No	4306703	5382	NA	2123222	3612	NA
Peripheral Vascular Disease	Yes	71021	259	2.87 (2.18, 3.79)	38476	172	2.59 (1.85, 3.63)
	No	4342254	5509	NA	2132541	3690	NA
Renal Disease	Yes	59062	501	7.01 (5.71, 8.61)	30440	387	7.83 (6.19, 9.90)
	No	4354212	5267	NA	2140578	3476	NA
Cardiac Valvular Disease	Yes	161728	503	2.51 (2.05, 3.08)	84034	327	2.30 (1.79, 2.95)
	No	4251546	5264	NA	2086983	3536	NA

* NA=not applicable for the reference group

Table 3

List of complications of patients undergoing total knee (TKA) and hip arthroplasty (THA). Unadjusted data are shown and numbers are based on weighted estimates.

Complications							
		TKA			THA		
Complications		Alive	Died	OR (95% CI)	Alive	Died	OR (95% CI)
Cerebrovascular Event	Yes	5187	478	76.73 (61.72, 95.40)	2800	292	63.34 (44.00, 83.57)
	No	4408088	5290	NA *	2168217	3571	NA
Pulmonary Complication	Yes	21877	2129	117.43 (103.92, 132.70)	9013	1344	128.04 (109.76, 149.37)
	No	4391397	3639	NA	2162004	2518	NA
Sepsis	Yes	4182	638	131.19 (107.99, 159.38)	2550	540	138.22 (110.92, 172.24)
	No	4409093	5130	NA	2168467	3323	NA
Myocardial Infarction	Yes	11927	1151	92.00 (79.29, 106.75)	6149	688	76.29 (63.00, 92.38)
	No	4401347	4617	NA	2164868	3175	NA
Cardiac Complications	Yes	256976	2475	12.15 (10.82, 13.65)	122636	1659	12.57 (10.91, 14.49)
	No	4156298	3293	NA	2048382	2204	NA
Pneumonia	Yes	30639	1155	35.82 (30.97, 41.44)	13639	729	36.83 (30.67, 44.22)
	No	4382635	4613	NA	2157379	3133	NA
Pulmonary Embolism	Yes	18645	712	33.20 (27.79, 39.67)	4468	337	46.32 (35.79, 59.96)
	No	4394629	5056	NA	2166549	3526	NA

* NA= not applicable for the reference group

Figure 1.
This figure shows the number of discharges and mortalities after total knee arthroplasty (TKA) by hospitalization day.

Figure 2.

This figure shows the number of discharges and mortalities after total hip arthroplasty (THA) by hospitalization day.

Table 1

Shown are the patient demographics and hospital details of total hip (THA) and knee arthroplasties (TKA). Unadjusted data are shown and percentages are based on weighted estimates.

Demographics						
Group	Primary TKA			Primary THA		
	Alive	Died	P-value	Alive	Died	P-value
N=	904818	1184		444437	792	
Weighted N=	4413274	5768		2171018	3863	
(%)	99.9	0.1		99.8	0.2	
Average age (years)	67.1	73.7	<.0001	65.3	74.9	
Average Comorbidity Index	0.57	0.69	<.0001	0.46	0.73	
Age groups (%)						
0-44	2.0	0.7		6.8	2.3	
45-64	36.4	15.2		36.4	14.1	
65-74	35.0	30.3	<.0001	29.3	22.5	<.0001
>75	26.6	53.8		27.4	61.2	
Gender (%)						
Female	63.9	48.8	<.0001	56.8	51.9	0.0056
Race (%)						
White	61.7	63.6		63.2	63.5	
Black	4.9	5.6		4.5	5.9	
Hispanic	3.5	3.3	0.0007	2.1	1.8	0.0224
Other	2.4	3.8		2.0	3.2	
Missing	27.5	23.7		28.2	25.5	
Admission Type (%)						
Emergent	1.1	3.6		1.8	13.2	
Elective	91.7	88.2	<.0001	91.7	75.8	<.0001
Urgent+Other	7.1	8.2		6.5	11.0	
Hospital Size (%)						
Small	14.5	11.9	0.0349	14.2	13.3	0.4234

Demographics								
	Primary TKA				Primary THA			
Group	Alive	Died	P-value		Alive	Died	P-value	
Medium	25.5	25.5			24.5	23.0		
Large	60.0	62.5			61.4	63.6		
Hospital Location (%)								
Rural	13.8	14.5	0.4843		11.6	13.1		0.1864
Hospital Teaching Status (%)								
Non-teaching	58.0	57.2	0.5893		52.1	52.6		0.7688
Years (%)								
1998–1999	11.6	17.1	<.0001			13.4	17.7	<.0001
2000–2001	13.5	17.1				15.3	18.6	
2002–2003	16.2	19.3				17.4	19.9	
2004–2005	21.0	19.9				20.4	18.9	
2006–2008	37.7	26.7				33.4	24.9	

Table 2

List of Comorbidities/Complications of patients undergoing total hip (THA) and knee arthroplasty (TKA). Unadjusted data are shown and percentages are based on weighted estimates.

Comorbidities	Comorbidities					
	TKA			THA		
	Alive (%)	Died (%)	P value	Alive (%)	Died (%)	P-value
Alcohol Abuse	0.5	1.1	0.0078	1.2	2.1	0.0167
Congestive Heart Failure	2.8	23.6	<.0001	2.6	24.8	<.0001
Chronic Lung Disease	12.4	19.3	<.0001	12.3	22.4	<.0001
Coagulopathy	1.1	6.1	<.0001	1.2	10.0	<.0001
Uncomplicated Diabetes Mellitus	16.7	15.6	0.3332	10.7	10.9	0.8086
Complicated Diabetes Mellitus	1.2	2.3	0.0002	0.8	1.8	0.0008
Liver Disease	0.5	1.0	0.0343	0.7	2.2	<.0001
Fluid and Electrolyte Disturbances	6.2	27.1	<.0001	6.1	34.5	<.0001
Cancer	0.5	0.8	0.0874	0.6	1.6	0.0008
Metastatic Cancer	0.1	0.6	<.0001	0.3	4.6	<.0001
Neurologic Disorders	2.4	6.7	<.0001	2.2	6.5	<.0001
Peripheral Vascular Disease	1.6	4.5	<.0001	1.8	4.5	<.0001
Renal Disease	1.3	8.7	<.0001	1.4	10.0	<.0001
Cardiac Valvular Disease	3.7	8.7	<.0001	3.9	8.5	<.0001

Table 3

List of complications of patients undergoing total hip (THA) and knee arthroplasties (TKA). Unadjusted data are shown and percentages are based on weighted estimates.

Complications	Complications				
	TKA			THA	
	Alive (%)	Died (%)	P value	Alive (%)	Died (%)
Cerebrovascular Event	0.1	8.3	<.0001	0.1	7.6
Pulmonary Complication	0.5	36.9	<.0001	0.4	34.8
Sepsis	0.1	11.1	<.0001	0.1	14.0
Myocardial Infarction	0.3	20.0	<.0001	0.3	17.8
Cardiac Complications	5.8	42.9	<.0001	5.6	42.9
Pneumonia	0.7	20.0	<.0001	0.6	18.9
Pulmonary Embolism	0.4	12.3	<.0001	0.2	8.7

Table 4

Multivariate analysis of risk factors and comorbidities for perioperative mortality after total hip (THA) and knee arthroplasty (TKA). Adjusted data are shown.

Category	Variable	Odds Ratio	95% Confidence Intervals	P-value
Age (Reference: 45–46 years)	0–44 years	0.71	0.46	1.10
	65–74	1.84	1.58	2.14
	>=75	3.70	3.21	4.26
Gender (Reference: Female)	Male	1.71	1.55	1.88
Race (Reference: White)	Black	1.37	1.11	1.68
	Hispanic	0.87	0.61	1.25
	Other	2.00	1.54	2.60
	Missing	0.93	0.83	1.04
Surgery type (Reference=Hip) in Emergent Admissions *	TKA	0.54	0.36	0.80
Surgery type (Reference=Hip) in Elective Admissions *	TKA	0.88	0.79	0.97
Surgery type (Reference=Hip) in Urgent Admissions *	TKA	0.62	0.45	0.84
Admission Type (Reference: Urgent) in THA **	Emergent	2.36	1.71	3.27
	Elective	0.62	0.49	0.80
Admission Type (Reference: Urgent) in TKA **	Emergent	2.06	1.40	3.03
	Elective	0.89	0.71	1.11
Years (Reference: 1998–1999)	2000–2001	0.93	0.79	1.10
	2002–2003	0.86	0.73	1.00
	2004–2005	0.68	0.58	0.79
	2006–2008	0.46	0.39	0.54
Comorbidities (Reference: Absence of Disease)	Chronic Lung Disease	1.45	1.28	1.63
	Congestive Heart Failure	5.15	4.55	5.83
	Coagulopathy	3.23	2.65	3.95
	Neurologic Disease	2.47	2.04	3.00
	Peripheral Vascular Disease	1.44	1.13	1.84
	Renal Disease	3.25	2.68	3.93

Category	Variable	Odds Ratio	95% Confidence Intervals	P-value
	Electrolyte/Fluid Abnormality	4.09	3.65	<.0001
	Metastatic Cancer	5.66	3.85	<.0001
	Liver Disease	1.95	1.27	0.0025*

* Non-significant when Bonferroni test was applied for multiple comparisons.

** The interaction effect between procedure type and admission type was significant ($p=0.01$). Therefore the odds ratios of one variable were reported by stratifying by the other one.

Table 5

Multivariate analysis of the impact of complications on in-hospital-mortality of patients undergoing total hip (THA) and knee arthroplasty (TKA). Adjusted data are shown.

Complications	Odds Ratio	95% Confidence Intervals		p-value
Pulmonary Embolism	11.62	9.01	14.98	<.0001
Cerebrovascular Event	16.82	12.27	23.07	<.0001
Pulmonary Compromise	22.40	18.75	26.75	<.0001
Sepsis	8.56	6.39	11.45	<.0001
Acute Myocardial Infarction	7.61	6.07	9.54	<.0001
Cardiac Complication	4.11	3.58	4.72	<.0001
Pneumonia	2.18	1.73	2.74	<.0001

Model covariates included procedure type, age, gender, race, comorbidity burden, admission type, and the interaction between procedure type and admission type. Bonferroni test was applied for multiple comparisons but no change in significance was found.