

# Thirty-Day Postoperative Complications and Mortality Following Total Knee Arthroplasty

## Incidence and Risk Factors Among a National Sample of 15,321 Patients

Philip J. Belmont Jr., MD, Gens P. Goodman, DO, Brian R. Waterman, MD,  
Julia O. Bader, PhD, and Andrew J. Schoenfeld, MD

*Investigation performed at the Department of Orthopaedic Surgery, William Beaumont Army Medical Center,  
Texas Tech University Health Sciences Center, El Paso, Texas*

**Background:** The purpose of this investigation was to determine the incidence rates of, and identify risk factors for, thirty-day postoperative mortality and complications among more than 15,000 patients who underwent a primary unilateral total knee arthroplasty as documented in the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP).

**Methods:** The NSQIP database was queried to identify patients who had undergone primary unilateral total knee arthroplasty between 2006 and 2010. Patient demographics, medical history, and surgical characteristics were recorded, as were thirty-day postoperative complications, mortality, and length of hospital stay. Complications were divided into categories, which included major systemic complications (complications requiring complex medical intervention) and major local complications (including deep wound infection and peripheral nerve injury). Univariate testing and multivariate logistic regression analysis were used to identify significant independent predictors of the outcome measures.

**Results:** A total of 15,321 individuals underwent primary unilateral total knee arthroplasty. The mean age (and standard deviation) of the patients was  $67.3 \pm 10.2$  years. Obesity (a body mass index [BMI] of  $\geq 30$  kg/m<sup>2</sup>) was documented in 61.2% of cases, 18.2% of patients had diabetes, and 50% were graded as Class 3 or higher on the basis of the American Society of Anesthesiologists (ASA) classification system. The thirty-day mortality rate was 0.18%, and 5.6% of the patients experienced complications. Patient age (odds ratio [OR] = 1.12; 95% confidence interval [CI] = 1.06 to 1.17) and diabetes (OR = 2.99; 95% CI = 1.35 to 6.62) were independent predictors of mortality. A BMI of  $\geq 40$  kg/m<sup>2</sup> was an independent predictor of postoperative complications (OR = 1.47; 95% CI = 1.09 to 1.98). Patient age of eighty years or older, an ASA classification of  $\geq 3$ , and an operative time of  $>135$  minutes influenced the development of any postoperative complication as well as major and minor systemic complications. Cardiac disease (OR = 4.32; 95% CI = 1.01 to 18.45) and a BMI of  $\geq 40$  kg/m<sup>2</sup> (OR = 2.01; 95% CI = 1.02 to 3.97) were associated with minor local complications.

**Conclusions:** Patient age and diabetes increased the risk of mortality after primary total unilateral knee arthroplasty. Predictive factors impacting the development of postoperative complications included an ASA classification of  $\geq 3$ , increased operative time, increased age, and greater body mass.

**Level of Evidence:** Prognostic Level IV. See Instructions for Authors for a complete description of levels of evidence.

**Peer Review:** This article was reviewed by the Editor-in-Chief and one Deputy Editor, and it underwent blinded review by two or more outside experts. It was also reviewed by an expert in methodology and statistics. The Deputy Editor reviewed each revision of the article, and it underwent a final review by the Editor-in-Chief prior to publication. Final corrections and clarifications occurred during one or more exchanges between the author(s) and copyeditors.

**Disclosure:** One or more of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of an aspect of this work. In addition, one or more of the authors, or his or her institution, has had a financial relationship, in the thirty-six months prior to submission of this work, with an entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. No author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete **Disclosures of Potential Conflicts of Interest** submitted by authors are always provided with the online version of the article.

**Disclaimer:** Some authors are employees of the U.S. Federal Government and the United States Army. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of William Beaumont Army Medical Center, the Department of Defense, or United States government. The American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

Total knee arthroplasty is common and can restore function and improve quality of life for patients with knee arthritis that has not been effectively managed non-operatively<sup>1-5</sup>. However, total knee arthroplasty may be associated with serious complications that adversely affect outcomes and increase the likelihood of higher health-care costs, disability, and death<sup>6,7</sup>. The prevalence of diabetes has increased by 32% over the past ten years<sup>8,9</sup>, while the obesity rate (a body mass index [BMI] of  $\geq 30$  kg/m<sup>2</sup>) has risen by 129%<sup>10</sup>. Obesity is a major risk factor for the development of knee osteoarthritis<sup>11,12</sup> and, consequently, the proportion of obese patients who undergo total knee arthroplasty has also increased<sup>13</sup>. In addition to there being more chronic medical conditions within the general population, total knee arthroplasty has been thought to be offered more frequently to patients with complex comorbidities because of surgeon confidence in enhanced perioperative management<sup>7</sup>.

Many studies that have provided comprehensive evaluations of postoperative mortality and morbidity after total knee arthroplasty have been single-center/regional studies<sup>6,14,15</sup> or have relied on state/national registries with limited case-specific data<sup>7,16,17</sup>. In addition, the authors of these studies have tended to group together both primary and revision total hip and total knee arthroplasty complications, and thus the resultant capacity to generalize these findings to the U.S. population undergoing a primary unilateral total knee arthroplasty may be limited.

Few well-designed studies, with sufficient sample size and adjustment for potential confounding variables, have examined risk factors such as age, sex, BMI, specific medical comorbidities, and operative time and their effect on postoperative mortality, morbidity, and length of hospital stay following total knee arthroplasty. The purpose of this investigation was to determine the incidence rates of, and identify risk factors for, thirty-day postoperative mortality and complications as well as their influence on length of hospital stay among more than 15,000 patients who underwent primary unilateral total knee arthroplasty as documented in the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP).

## Materials and Methods

Following institutional review board approval, we obtained NSQIP data from the years 2006 to 2010. The NSQIP database has been successfully employed in previous prognostic studies regarding orthopaedic surgery<sup>18,19</sup>, including those that have examined aspects of total knee arthroplasty<sup>20</sup>, and NSQIP data have been proven to be consistently reliable, with interrater disagreement reported to be 1.6%<sup>21</sup>. Previous studies have detailed the NSQIP database methodology regarding case accrual, preparation of the data set, validity, and reliability<sup>21,22</sup>. At all medical centers that participate in NSQIP, patient demographic data and medical history are recorded by assigned NSQIP staff members. Site visits, as well as system auditing, are performed to ensure data accuracy. Patients included in the NSQIP database are prospectively followed for thirty days postoperatively, and postoperative complications as well as mortality are recorded. Any additional surgical procedures performed within thirty days postoperatively are not registered with the database as new procedures.

The Current Procedural Terminology code 27447 (total knee arthroplasty) was employed in this investigation to identify all individuals who had undergone a primary unilateral total knee arthroplasty. Excluded were patients for whom additional codes associated with the index procedure

TABLE I Patient Demographic and Preoperative Characteristics

Characteristic	Value
Age (n = 15,321)	
Mean and standard deviation (yr)	67.3 ± 10.2
No. (%) in age groups	
≤59 yr	3529 (23.0)
60-69 yr	5225 (34.1)
70-79 yr	4717 (30.8)
≥80 yr	1850 (12.1)
Sex (n = 15,287) (no. [%])	
Male	5428 (35.5)
Female	9859 (64.5)
BMI (n = 15,189)	
Mean and standard deviation (kg/m <sup>2</sup> )	32.8 ± 7.3
No. (%) in BMI groups	
≤24.9 kg/m <sup>2</sup>	1593 (10.5)
25.0-29.9 kg/m <sup>2</sup>	4297 (28.3)
30.0-34.9 kg/m <sup>2</sup>	4292 (28.3)
35.0-39.9 kg/m <sup>2</sup>	2760 (18.2)
≥40.0 kg/m <sup>2</sup>	2247 (14.8)
Operative time (n = 15,319)	
Mean and standard deviation (min)	96.9 ± 37.9
American Society of Anesthesiologists classification (n = 15,286) (no. [%])	
1 or 2: no or mild disturbance	7637 (50.0)
3 or 4: severe or life-threatening disturbance	7649 (50.0)
Medical comorbidities (no. [%])	
Diabetes	2795 (18.2)
Smoking (current smoker within one year)	1328 (8.7)
Regular alcohol use*	322 (2.1)
Chronic obstructive pulmonary disease	596 (3.9)
Cardiac issues (congestive heart failure/myocardial infarction)†	1650 (10.8)
Hypertension	10,721 (70.0)
Peripheral vascular disease	107 (0.7)
Renal insufficiency	37 (0.2)
Steroid use	384 (2.5)
Length of stay (n = 15,215) (no. [%])	
≥4 days	4573 (30.1)
≤3 days	10,642 (69.9)

\*More than two alcoholic drinks per day in the two weeks before admission. †Congestive heart failure within thirty days before surgery, chronic congestive heart failure with new signs or symptoms within thirty days before surgery, or a history of myocardial infarction within six months before surgery.

indicated that they had undergone bilateral or staged knee arthroplasty. Demographic information as reported to the NSQIP, including medical history and current medical comorbidities, was catalogued (Table I).

**TABLE II Total Number and Percentage of Major and Minor Systemic and Local Complications**

Characteristic	No. of Complications (% of Patients)
<b>Major systemic complications</b>	
Pulmonary embolism	120 (0.78%)
Other systemic complication	71 (0.46%)
Postoperative sepsis	67 (0.44%)
Septic shock	20 (0.13%)
Cerebrovascular accident	17 (0.11%)
Acute renal failure	15 (0.10%)
Cardiac arrest requiring cardiopulmonary resuscitation	14 (0.09%)
<b>Minor systemic complications</b>	
Urinary tract infection	228 (1.49%)
Deep venous thrombosis	206 (1.34%)
Pneumonia	56 (0.37%)
Renal insufficiency	19 (0.12%)
<b>Major local complications</b>	
Deep wound infection/organ space infection	46 (0.30%)
Peripheral nerve injury	16 (0.10%)
<b>Minor local complications</b>	
Superficial wound infection	121 (0.79%)
Wound dehiscence	41 (0.27%)

Intraoperative characteristics, such as type of anesthesia and operative times, were recorded. The length of hospital stay as well as thirty-day postoperative complications and mortality were abstracted. Both systemic and local complications were categorized as either major or minor, based on accepted determinations from the literature<sup>6,14,15</sup>, by which major systemic complications necessitated complex medical intervention and major local complications consisted of deep wound infection or peripheral nerve injury (Tables II and III).

### Statistical Analysis

Univariate logistic regression analysis and the chi-square statistic were used to determine the effect of individual risk factors on mortality, the development of one or more complications as well as major and minor systemic or local complications, and the length of hospital stay. The primary patient-based predictors included age (categorized as fifty-nine years of age or younger, sixty to sixty-nine years of age, seventy to seventy-nine years of age, or eighty years of age and older), sex, BMI (categorized as  $\leq 24.9$ , 25.0 to 29.9, 30.0 to 34.9, 35.0 to 39.9, or  $\geq 40$  kg/m<sup>2</sup>), American Society of Anesthesiologists (ASA) classification (1 or 2 compared with 3 or 4), diabetes, and cardiac disease. The primary surgical risk factor evaluated was operative time. The ASA score is a validated measure of perioperative mortality and immediate postoperative morbidity<sup>23,24</sup>. Multivariate logistic regression analysis was conducted for factors with a p value of  $<0.2$  in the initial univariate and chi-square testing to evaluate the effect of the individual risk factors on morbidity, mortality, and length of hospital stay while controlling for other factors in the model. Odds ratios (ORs) and 95% confidence intervals (CIs) were reported for both univariate and multivariate analyses. Significant independent predictor variables were determined to be those that maintained p values of  $<0.05$  with the OR and 95% CI exclusive of 1.0 following multivariate analysis. The C-statistic and the Hosmer-Lemeshow goodness-of-fit test were used to assess the fitness of the logistic regression model.

### Source of Funding

No funding was received in support of this study.

### Results

There were 15,321 patients in the NSQIP database who underwent primary unilateral total knee arthroplasty between 2006 and 2010. The average age (and standard deviation) of the patients at the time of the index procedure was  $67.3 \pm 10.2$  years. The majority of the patients were female (64.5%), had a BMI of  $\geq 30$  kg/m<sup>2</sup> (61.2%), and were nonsmokers (91.3%) (Table I). Fifty percent were classified as ASA Class 3 or higher. The most common medical comorbidities were hypertension (in 70.0% of the patients), diabetes mellitus (in 18.2%), and cardiac disease (in 10.8%) (Table I). The mean operative time (skin-to-skin) was  $97 \pm 38$  minutes. For the purposes of statistical analysis, comparisons were made between operative times that exceeded the mean by one standard deviation (135 minutes) and those that were concluded in less than 135 minutes. The length of stay was three days or less for 69.9% of the patients.

The thirty-day mortality rate was 0.18%. In the same time period, 1057 complications were documented among 851 (5.55%) of the patients (Tables II and III). There were 324 major systemic complications among 280 (1.83%) of the patients and 509 minor systemic complications among 491 (3.20%) of the patients. Of the major systemic events, 46.6% were cardiovascular in origin, with pulmonary embolism being the most prevalent major systemic complication (noted in 0.78% of the patients). Urinary tract infection and deep venous thrombosis were the most common minor systemic complications, documented in 1.49% and 1.34% of the patients, respectively. There were sixty-two major local complications and 162 minor local complications; sixty-two patients (0.40%) had major local complications and 158 (1.03%) had minor local complications. The major local complications consisted of deep wound infection (0.30% of the patients) and peripheral nerve injury (0.10% of the patients). Superficial wound infection (0.79%) and wound dehiscence (0.27%) accounted for the minor local complications. The majority of complications were diagnosed within the first two weeks following surgery. Fifty-two percent of venous thromboembolic events were identified

**TABLE III Thirty-Day Mortality and Complication Rates**

Characteristic	Value	
	No. of Patients	%
Mortality	27	0.18%
Any complication	851	5.55%
Major systemic complication	280	1.83%
Minor systemic complication	491	3.20%
Major local complication	62	0.40%
Minor local complication	158	1.03%
Mortality or major complication	340	2.22%

**TABLE IV Results of Univariate and Chi-Square Analyses for the Influence of Risk Factors on Mortality, Any Complication, Major and Minor Systemic Complications, Minor Local Complications, and Length of Stay**

Outcome/Risk Factor	Odds Ratio (95% CI)
<b>Mortality</b>	
Age (continuous)	1.11 (1.06 to 1.17)
ASA classification $\geq 3$	2.86 (1.21 to 6.76)
Diabetes mellitus	3.09 (1.43 to 6.66)
<b>Any complication</b>	
BMI (continuous)	1.01 (1.01 to 1.02)
BMI $\geq 40$ versus $< 25$ kg/m <sup>2</sup>	1.35 (1.02 to 1.78)
Age (continuous)	1.02 (1.01 to 1.03)
Age $\geq 80$ versus $< 60$ yr	1.79 (1.42 to 2.26)
Diabetes mellitus	1.21 (1.02 to 1.43)
ASA classification $\geq 3$	1.68 (1.46 to 1.94)
Operative time $> 135$ min	1.56 (1.30 to 1.88)
<b>Major systemic complication</b>	
Age (continuous)	1.04 (1.02 to 1.05)
Age $\geq 80$ versus $< 60$ yr	2.77 (1.86 to 4.10)
Diabetes mellitus	1.36 (1.03 to 1.81)
ASA classification $\geq 3$	1.81 (1.41 to 2.31)
Operative time $> 135$ min	1.48 (1.07 to 2.03)
<b>Minor systemic complication</b>	
Age (continuous)	1.02 (1.01 to 1.03)
Age $\geq 80$ versus $< 60$ yr	1.95 (1.43 to 2.67)
ASA classification $\geq 3$	1.60 (1.33 to 1.92)
Operative time $> 135$ min	1.52 (1.19 to 1.93)
<b>Minor local complication</b>	
BMI (continuous)	1.04 (1.02 to 1.05)
BMI $\geq 40$ versus $< 25$ kg/m <sup>2</sup>	2.51 (1.28 to 4.92)
ASA classification $\geq 3$	2.11 (1.51 to 2.95)
Cardiac disease (myocardial infarction or congestive heart failure)	6.47 (1.53 to 27.30)
Operative time $> 135$ min	1.91 (1.29 to 2.82)
<b>Length of stay of <math>\geq 4</math> days</b>	
Female sex	1.22 (1.13 to 1.31)
Age (continuous)	1.02 (1.02 to 1.03)
Age 60-69 versus $< 60$ yr	1.16 (1.05 to 1.27)
Age 70-79 versus $< 60$ yr	1.43 (1.30 to 1.58)
Age $\geq 80$ versus $< 60$ yr	1.96 (1.73 to 2.21)
ASA classification $\geq 3$	1.58 (1.47 to 1.69)
Diabetes mellitus	1.27 (1.17 to 1.39)
Cardiac disease (myocardial infarction or congestive heart failure)	2.32 (1.16 to 4.65)
Operative time $> 135$ min	1.90 (1.72 to 2.10)

within the first three postoperative days, while 75% were diagnosed by postoperative day nine.

Among the twenty-seven patients who died, eighteen (67%) had sustained a total of forty-five complications. Cardiac

arrest (44% of the patients), systemic shock (18.5%), and renal failure (18.5%) were the most common specific complications among those who died. Overall, 340 (2.2%) of the patients either died or experienced a major complication in the first thirty days following primary total knee arthroplasty. Within this group, seven patients died after sustaining a major systemic complication and ten patients had two or more major systemic complications.

Univariate testing identified risk factors for mortality, any complication, major systemic complication, minor systemic complication, minor local complication, and a length of hospital stay of four days or more that met criteria for inclusion in multivariate testing (Table IV). Notable among these were the association of diabetes mellitus with mortality (OR = 3.09; 95% CI = 1.43 to 6.66;  $p = 0.004$ ), a patient age of eighty years or older with major systemic complication (OR = 2.77; 95%

**TABLE V Significant Risk Factors for Mortality, Any Complication, Major and Minor Systemic Complications, Minor Local Complication, and Length of Stay as Determined by Multivariate Logistic Regression Analysis**

Risk Factor	Odds Ratio (95% CI)
<b>Mortality</b>	
Age (continuous)	1.12 (1.06 to 1.17)
Diabetes mellitus	2.99 (1.35 to 6.62)
<b>Any complication</b>	
BMI $\geq 40$ versus $< 25$ kg/m <sup>2</sup>	1.47 (1.09 to 1.98)
Age $\geq 80$ versus $< 60$ yr	1.94 (1.51 to 2.50)
ASA classification $\geq 3$	1.49 (1.28 to 1.73)
Operative time $> 135$ min	1.60 (1.33 to 1.94)
<b>Major systemic complication</b>	
Age $\geq 80$ versus $< 60$ yr	2.63 (1.76 to 3.92)
ASA classification $\geq 3$	1.58 (1.22 to 2.04)
Operative time $> 135$ min	1.54 (1.11 to 2.14)
<b>Minor systemic complication</b>	
Female sex	1.22 (1.01 to 1.48)
Age $\geq 80$ versus $< 60$ yr	1.87 (1.36 to 2.57)
ASA classification $\geq 3$	1.49 (1.23 to 1.81)
Operative time $> 135$ min	1.64 (1.28 to 2.09)
<b>Minor local complication</b>	
BMI $\geq 40$ versus $< 25$ kg/m <sup>2</sup>	2.01 (1.02 to 3.97)
ASA classification $\geq 3$	1.88 (1.33 to 2.65)
Cardiac disease	4.32 (1.01 to 18.45)
Operative time $> 135$ min	1.85 (1.25 to 2.74)
<b>Length of stay of <math>\geq 4</math> days</b>	
Female sex	1.27 (1.18 to 1.37)
Age 60-69 versus $< 60$ yr	1.16 (1.05 to 1.28)
Age 70-79 versus $< 60$ yr	1.43 (1.29 to 1.58)
Age $\geq 80$ versus $< 60$ yr	1.94 (1.72 to 2.20)
ASA classification $\geq 3$	1.47 (1.36 to 1.58)
Diabetes mellitus	1.16 (1.06 to 1.27)
Operative time $> 135$ min	2.08 (1.88 to 2.31)

CI = 1.86 to 4.10;  $p < 0.001$ ), and either a BMI of  $\geq 40$  kg/m<sup>2</sup> (OR 2.51; 95% CI = 1.28 to 4.92;  $p < 0.0003$ ) or cardiac disease (OR = 6.47; 95% CI = 1.53 to 27.30;  $p = 0.01$ ) with minor local complication. All maintained an OR of  $>2.0$ .

Multivariate logistic regression analysis determined the risk factors for mortality, any complication, major systemic complication, minor systemic complication, minor local complication, and a length of stay of four days or more (Table V). Diabetes mellitus (OR = 2.99; 95% CI = 1.35 to 6.62;  $p < 0.006$ ) and age (OR = 1.12 per annual increase in patient age; 95% CI = 1.06 to 1.17;  $p < 0.0001$ ) were significant independent predictors of mortality. Diabetes mellitus was identified as a medical comorbidity in 18.2% of patients and increased the overall risk of mortality by 300%. A BMI of  $\geq 40$  kg/m<sup>2</sup> was an independent predictor of the development of any postoperative complication (OR = 1.47; 95% CI = 1.09 to 1.98). Patient age of eighty years or older, an ASA classification of  $\geq 3$ , and an operative time of  $>135$  minutes were important predictors of the development of any postoperative complication as well as major and minor systemic complications (Table V). Female sex, patient age of eighty years or older, an ASA classification of  $\geq 3$ , and an operative time of  $>135$  minutes were significant predictors of one or more minor systemic complications. Cardiac disease, a BMI of  $\geq 40$  kg/m<sup>2</sup>, an ASA classification of  $\geq 3$ , and an operative time of  $>135$  minutes were significant predictors of one or more minor local complications. Female sex; age groups sixty to sixty-nine years, seventy to seventy-nine years, and eighty years and older; an ASA classification of  $\geq 3$ ; diabetes mellitus; and an operative time of  $>135$  minutes were independent predictors of a length of stay of four days or more (Table V).

The C-statistic (0.76) indicated that the model used had a very good distinguishing ability to evaluate mortality, while its distinguishing capacity for the other factors evaluated was more moderate. The goodness-of-fit test showed no evidence of a lack of fit for any characteristic analyzed in this study.

## Discussion

Total knee arthroplasty has been associated with substantial mortality and life-altering complications<sup>6,14,15,20,25</sup>. Improving the quality of care for patients who undergo total knee arthroplasty by identifying specific patient-based and surgical variables capable of impacting outcomes remains a continuing priority<sup>20,26</sup>. This investigation examined the risk factors for thirty-day postoperative mortality and complications following primary unilateral total knee arthroplasty in a data set from hospitals throughout the United States.

The average age of the patients who underwent unilateral total knee arthroplasty and the prevalence of medical comorbidities, including diabetes mellitus (in 18.2% of the patients) and a BMI of  $\geq 30$  kg/m<sup>2</sup> (61.2% of the patients), were similar to those noted in contemporary studies<sup>1,7,13,24,27-30</sup>, as was the mean operative time<sup>31</sup>. The 0.18% mortality rate identified in this study is on the lower end of the spectrum reported for both unilateral and bilateral total knee arthroplasties (0.21% to 0.36%)<sup>32,33</sup>. In these aforementioned investigations, bilateral

total knee arthroplasties, which are associated with higher mortality rates<sup>33</sup>, accounted for 3% to 12% of the total procedures. Our multivariate logistic regression analyses identified diabetes mellitus and increased patient age as independent predictors of mortality (Table V). Other investigators who have used multivariate analyses have reported elevated thirty-day mortality rates with increased patient age<sup>33,34</sup>, but none have previously identified diabetes mellitus as a risk factor, to our knowledge.

Of the patients in the present study who underwent a unilateral total knee arthroplasty, 5.6% developed a complication (Table III). Multivariate analyses demonstrated that a patient age of eighty years or older, an operative time of  $>135$  minutes, an ASA classification of  $\geq 3$ , and a BMI of  $\geq 40$  kg/m<sup>2</sup> were the most important risk factors, in descending order, for the development of any complication (Table V). These findings were consistent with those of previous studies from single institutions that presented major and minor systemic and local complication rates for all hip and knee reconstructive procedures and that found age, obesity, and a history of coexistent diseases as risk factors<sup>6,14,35</sup>. In the present study, we comprehensively evaluated complications to quantify, with the use of multivariate analysis, the elevation in relative risk associated with prolonged surgical times and with BMI. Surgical efficiency, represented by decreased operative times, should be a universal goal, given that longer surgical times for total knee arthroplasty have been associated with venous thromboembolism, neurologic dysfunction, and decreased implant survivorship<sup>36-38</sup>.

In the United States, the prevalence of obesity (a BMI of  $\geq 30$  kg/m<sup>2</sup>) is currently 34.3%, and the prevalence of morbid obesity (a BMI of  $\geq 40$  kg/m<sup>2</sup>) has increased 428% in the last three decades, to 6.0%<sup>10</sup>. In our study, only patients with a BMI of  $\geq 40$  kg/m<sup>2</sup>, when compared with those with a BMI of  $<25$  kg/m<sup>2</sup>, had a significantly increased risk of developing any complication (OR = 1.47; 95% CI = 1.09 to 1.98). This study underscores the need to develop and evaluate weight-loss programs/interventions, especially for patients who are morbidly obese and have knee osteoarthritis<sup>39,40</sup>.

Major and minor systemic complications occurred in 1.83% and 3.20% of patients who underwent unilateral total knee arthroplasty, respectively (Table III). The most common major complications were pulmonary embolism (in 0.78% of the patients) and postoperative sepsis/septic shock (in 0.57% of the patients). Pulmonary embolism is the most common major systemic complication following total knee arthroplasty, with an incidence of 1.82%<sup>15</sup>. The most common minor complications were urinary tract infection, deep venous thrombosis, and pneumonia. Multivariate analyses ascertained that a patient age of eighty years or older was the most important risk factor for the development of one or more major and one or more minor systemic complications, and an ASA classification of  $\geq 3$  and an operative time of  $>135$  minutes were also significant risk factors for major and minor systemic complications (Table V).

Major and minor local complications occurred in 0.40% and 1.03% of the patients, respectively (Table III). The most

common major local complications were deep wound infection and peripheral nerve injury, while the most common minor local complications were superficial wound infection and wound dehiscence. The thirty-day periprosthetic knee infection rate of 0.30% is similar to the 0.33% acute periprosthetic infection rate reported in a cohort study of 4185 total knee arthroplasties<sup>41</sup>. Since nearly 75% of the major local complications within thirty days postoperatively were deep wound infections, and the average time to diagnosis of an infection after index total knee arthroplasty has been reported to be 431 days<sup>41</sup>, we employed extreme caution in interpreting the finding of no potential risk factors for the development of major local complications. A recent meta-analysis of patients with total knee arthroplasty<sup>42</sup> reported a significantly increased risk for both superficial and deep infections for patients with a BMI of  $\geq 30$  kg/m<sup>2</sup>. Other, prospective research has shown that a BMI of  $\geq 40$  kg/m<sup>2</sup> and diabetes mellitus are significant risk factors for the development of a periprosthetic infection within the first year after total knee arthroplasty<sup>41,43</sup>.

In the current study, multivariate analyses determined that patients with cardiac disease had a fourfold increase in risk of developing one or more minor local complications, and that a BMI of  $\geq 40$  kg/m<sup>2</sup>, an ASA classification of  $\geq 3$ , and an operative time of  $>135$  minutes were also significant independent predictors of one or more minor local complications. We found that only those with a BMI of  $\geq 40$  kg/m<sup>2</sup>, when compared with the group of patients with a BMI of  $<25$  kg/m<sup>2</sup>, had a significantly increased risk of developing a minor local complication (OR = 2.51; 95% CI = 1.28 to 1.92). Wound complications necessitating surgical treatment within thirty days after primary total knee arthroplasty are associated with a greater than sevenfold increased risk for the development of deep infection within two years<sup>44</sup>. Thus, the potential exists for minor local complications to develop into periprosthetic infections.

The use of national registry data is one of the main limitations of this analysis. Patient information, including complications, is restricted to the data documented within the NSQIP database, and several potential confounders were not reported and cannot be controlled. These include compliance with and manner of deep venous thrombosis chemoprophylaxis,

the use of antibiotic cement, the presence and management of perioperative hyperglycemia, and the severity of coexistent medical conditions. Although the NSQIP has a robust oversight program and proactively engages in actions intended to minimize coding errors<sup>18,19,21,22</sup>, the potential for the underreporting of complications within the NSQIP data set has been raised in the past<sup>22</sup>. Additionally, the overall complication rates cannot be extrapolated beyond thirty days.

Of the more than 15,000 patients who underwent unilateral total knee arthroplasty, 0.18% died within thirty days postoperatively and 5.6% experienced complications. The results of this study underscore that diabetes mellitus and increased age are notable risk factors for mortality. Additionally, a patient age of eighty years or older, an operative time of  $>135$  minutes, an ASA classification of  $\geq 3$ , and a BMI of  $\geq 40$  kg/m<sup>2</sup> were identified as risk factors for the development of complications following surgery. The 2.2% mortality or major complication rate that we found for patients who underwent a unilateral total knee arthroplasty confirms the need for diligent medical management during the perioperative period. ■

Philip J. Belmont Jr., MD  
Gens P. Goodman, DO  
Brian R. Waterman, MD  
Andrew J. Schoenfeld, MD  
Department of Orthopaedic Surgery,  
William Beaumont Army Medical Center,  
Texas Tech University Health Sciences Center,  
5005 North Piedras Street,  
El Paso, TX 79920.  
E-mail address for P.J. Belmont, Jr.: philip.belmont@us.army.mil.  
E-mail address for G.P. Goodman: gens.goodman@us.army.mil.  
E-mail address for B.R. Waterman: brian.r.waterman@us.army.mil.  
E-mail address for A.J. Schoenfeld: ajschoen@neomed.edu

Julia O. Bader, PhD  
Statistical Consulting Laboratory,  
137 Bell Hall, University of Texas at El Paso,  
El Paso, TX 79968.  
E-mail address: jbader@utep.edu

## References

- Kane RL, Saleh KJ, Wilt TJ, Bershadsky B. The functional outcomes of total knee arthroplasty. *J Bone Joint Surg Am.* 2005 Aug;87(8):1719-24.
- Ethgen O, Bruyère O, Richy F, Dardennes C, Reginster JY. Health-related quality of life in total hip and total knee arthroplasty. A qualitative and systematic review of the literature. *J Bone Joint Surg Am.* 2004 May;86(5):963-74.
- Garrett WE Jr, Swionkowski MF, Weinstein JN, Callaghan J, Rosier RN, Berry DJ, Harrast J, Derosa GP. American Board of Orthopaedic Surgery Practice of the Orthopaedic Surgeon: Part-II, certification examination case mix. *J Bone Joint Surg Am.* 2006 Mar;88(3):660-7.
- Kim S. Changes in surgical loads and economic burden of hip and knee replacements in the US: 1997-2004. *Arthritis Rheum.* 2008 Apr 15;59(4):481-8.
- Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am.* 2007 Apr;89(4):780-5.
- Parvizi J, Mui A, Purtill JJ, Sharkey PF, Hozack WJ, Rothman RH. Total joint arthroplasty: When do fatal or near-fatal complications occur? *J Bone Joint Surg Am.* 2007 Jan;89(1):27-32.
- Memtsoudis SG, Della Valle AG, Besculides MC, Gaber L, Laskin R. Trends in demographics, comorbidity profiles, in-hospital complications and mortality associated with primary knee arthroplasty. *J Arthroplasty.* 2009 Jun;24(4):518-27. Epub 2008 Apr 15.
- Center for Disease Control and Prevention. 2003 National Diabetes Fact Sheet. Available at: <http://www.cdc.gov/diabetes/pubs/general.htm>. Accessed August 28, 2013.
- Center for Disease Control and Prevention. 2011 National Diabetes Fact Sheet. Available at: <http://www.cdc.gov/diabetes/pubs/factsheet11.htm>. Accessed August 28, 2013.
- National Center of Health Statistics Health E-Stats. Prevalence of overweight, obesity, and extreme obesity among adults: United States, trends 1960-1962 through 2007-2008. Available at [http://www.cdc.gov/nchs/data/hestat/obesity\\_adult\\_07\\_08/obesity\\_adult\\_07\\_08.htm](http://www.cdc.gov/nchs/data/hestat/obesity_adult_07_08/obesity_adult_07_08.htm). Accessed August 28, 2013.
- Felson DT, Lawrence RC, Dieppe PA, Hirsch R, Helmick CG, Jordan JM, Kington RS, Lane NE, Nevitt MC, Zhang Y, Sowers M, McAlindon T, Spector TD, Poole AR, Yanovski SZ, Ateshian G, Sharma L, Buckwalter JA, Brandt KD, Fries JF.

Osteoarthritis: new insights. Part 1: the disease and its risk factors. *Ann Intern Med.* 2000 Oct 17;133(8):635-46.

12. Manek NJ, Hart D, Spector TD, MacGregor AJ. The association of body mass index and osteoarthritis of the knee joint: an examination of genetic and environmental influences. *Arthritis Rheum.* 2003 Apr;48(4):1024-9.
13. Singh JA, Jensen MR, Harmsen WS, Gabriel SE, Lewallen DG. Cardiac and thromboembolic complications and mortality in patients undergoing total hip and total knee arthroplasty. *Ann Rheum Dis.* 2011 Dec;70(12):2082-8. Epub 2011 Oct 21.
14. Higuera CA, Elsharkawy K, Klika AK, Broccone M, Barsoum WK. 2010 Mid-America Orthopaedic Association Physician in Training Award: predictors of early adverse outcomes after knee and hip arthroplasty in geriatric patients. *Clin Orthop Relat Res.* 2011 May;469(5):1391-400. Epub 2011 Feb 23.
15. Pulido L, Parvizi J, Macgibeny M, Sharkey PF, Purtill JJ, Rothman RH, Hozack WJ. In hospital complications after total joint arthroplasty. *J Arthroplasty.* 2008 Sep;23(6)(Suppl 1):139-45.
16. Jain NB, Guller U, Pietrobon R, Bond TK, Higgins LD. Comorbidities increase complication rates in patients having arthroplasty. *Clin Orthop Relat Res.* 2005 Jun;(435):232-8.
17. SooHoo NF, Lieberman JR, Ko CY, Zingmond DS. Factors predicting complication rates following total knee replacement. *J Bone Joint Surg Am.* 2006 Mar;88(3):480-5.
18. Belmont PJ Jr, Davey S, Orr JD, Ochoa LM, Bader JO, Schoenfeld AJ. Risk factors for 30-day postoperative complications and mortality after below-knee amputation: a study of 2,911 patients from the national surgical quality improvement program. *J Am Coll Surg.* 2011 Sep;213(3):370-8. Epub 2011 Jul 01.
19. Schoenfeld AJ, Ochoa LM, Bader JO, Belmont PJ Jr. Risk factors for immediate postoperative complications and mortality following spine surgery: a study of 3475 patients from the National Surgical Quality Improvement Program. *J Bone Joint Surg Am.* 2011 Sep 7;93(17):1577-82.
20. Pugely AJ, Martin CT, Gao Y, Mendoza-Lattes S, Callaghan JJ. Differences in short-term complications between spinal and general anesthesia for primary total knee arthroplasty. *J Bone Joint Surg Am.* 2013 Feb 6;95(3):193-9.
21. Shiloach M, Frencher SK Jr, Steeger JE, Rowell KS, Bartzokis K, Tomeh MG, Richards KE, Ko CY, Hall BL. Toward robust information: data quality and inter-rater reliability in the American College of Surgeons National Surgical Quality Improvement Program. *J Am Coll Surg.* 2010 Jan;210(1):6-16. Epub 2009 Nov 22.
22. Koch CG, Li L, Hixson E, Tang A, Phillips S, Henderson JM. What are the real rates of postoperative complications: elucidating inconsistencies between administrative and clinical data sources. *J Am Coll Surg.* 2012 May;214(5):798-805. Epub 2012 Mar 14.
23. Dripps RD, Lamont A, Eckenhoff JE. The role of anesthesia in surgical mortality. *JAMA.* 1961 Oct 21;178:261-6.
24. Weaver F, Hynes D, Hopkinson W, Wixson R, Khuri S, Daley J, Henderson WG. Preoperative risks and outcomes of hip and knee arthroplasty in the Veterans Health Administration. *J Arthroplasty.* 2003 Sep;18(6):693-708.
25. Cushner F, Agnelli G, FitzGerald G, Warwick D. Complications and functional outcomes after total hip arthroplasty and total knee arthroplasty: results from the Global Orthopaedic Registry (GLORY). *Am J Orthop (Belle Mead NJ).* 2010 Sep;39(9)(Suppl):22-8.
26. Maloney WJ. National Joint Replacement Registries: has the time come? *J Bone Joint Surg Am.* 2001 Oct;83(10):1582-5.
27. Suleiman LI, Ortega G, Ong'uti SK, Gonzalez DO, Tran DD, Onyike A, Turner PL, Fullum TM. Does BMI affect perioperative complications following total knee and hip arthroplasty? *J Surg Res.* 2012 May 1;174(1):7-11. Epub 2011 Jun 25.
28. Bolognesi MP, Marchant MH Jr, Viens NA, Cook C, Pietrobon R, Vail TP. The impact of diabetes on perioperative patient outcomes after total hip and total knee arthroplasty in the United States. *J Arthroplasty.* 2008 Sep;23(6)(Suppl 1):92-8.
29. Dowsey MM, Liew D, Choong PF. Economic burden of obesity in primary total knee arthroplasty. *Arthritis Care Res (Hoboken).* 2011 Oct;63(10):1375-81.
30. Namba RS, Paxton L, Fithian DC, Stone ML. Obesity and perioperative morbidity in total hip and total knee arthroplasty patients. *J Arthroplasty.* 2005 Oct;20(7)(Suppl 3):46-50.
31. Ong KL, Lau E, Manley M, Kurtz SM. Patient, hospital, and procedure characteristics influencing total hip and knee arthroplasty procedure duration. *J Arthroplasty.* 2009 Sep;24(6):925-31. Epub 2008 Oct 05.
32. Gill GS, Mills D, Joshi AB. Mortality following primary total knee arthroplasty. *J Bone Joint Surg Am.* 2003 Mar;85(3):432-5.
33. Parvizi J, Sullivan TA, Trousdale RT, Lewallen DG. Thirty-day mortality after total knee arthroplasty. *J Bone Joint Surg Am.* 2001 Aug;83(8):1157-61.
34. Parry MC, Smith AJ, Blom AW. Early death following primary total knee arthroplasty. *J Bone Joint Surg Am.* 2011 May 18;93(10):948-53.
35. Patel AD, Albrizio M. Relationship of body mass index to early complications in knee replacement surgery. *Arch Orthop Trauma Surg.* 2008 Jan;128(1):5-9. Epub 2007 May 24.
36. Jaffer AK, Barsoum WK, Krebs V, Hurbaneck JG, Morra N, Brotman DJ. Duration of anesthesia and venous thromboembolism after hip and knee arthroplasty. *Mayo Clin Proc.* 2005 Jun;80(6):732-8.
37. Horlocker TT, Hebl JR, Gali B, Jankowski CJ, Burkle CM, Berry DJ, Zepeda FA, Stevens SR, Schroeder DR. Anesthetic, patient, and surgical risk factors for neurologic complications after prolonged total tourniquet time during total knee arthroplasty. *Anesth Analg.* 2006 Mar;102(3):950-5.
38. Ong KL, Lau E, Manley M, Kurtz SM. Effect of procedure duration on total hip arthroplasty and total knee arthroplasty survivorship in the United States Medicare population. *J Arthroplasty.* 2008 Sep;23(6)(Suppl 1):127-32. Epub 2008 Jun 13.
39. Christensen R, Bartels EM, Astrup A, Bliddal H. Effect of weight reduction in obese patients diagnosed with knee osteoarthritis: a systematic review and meta-analysis. *Ann Rheum Dis.* 2007 Apr;66(4):433-9. Epub 2007 Jan 04.
40. Messier SP, Loeser RF, Miller GD, Morgan TM, Rejeski WJ, Sevick MA, Ettinger WH Jr, Pahor M, Williamson JD. Exercise and dietary weight loss in overweight and obese older adults with knee osteoarthritis: the Arthritis, Diet, and Activity Promotion Trial. *Arthritis Rheum.* 2004 May;50(5):1501-10.
41. Pulido L, Ghanem E, Joshi A, Purtill JJ, Parvizi J. Periprosthetic joint infection: the incidence, timing, and predisposing factors. *Clin Orthop Relat Res.* 2008 Jul;466(7):1710-5. Epub 2008 Apr 18.
42. Kerkhoffs GMMJ, Servien E, Dunn W, Dahm D, Bramer JAM, Haverkamp D. The influence of obesity on the complication rate and outcome of total knee arthroplasty: a meta-analysis and systematic literature review. *J Bone Joint Surg Am.* 2012 Oct 17;94(20):1839-44.
43. Dowsey MM, Choong PF. Obese diabetic patients are at substantial risk for deep infection after primary TKA. *Clin Orthop Relat Res.* 2009 Jun;467(6):1577-81. Epub 2008 Oct 08.
44. Galat DD, McGovern SC, Larson DR, Harrington JR, Hanssen AD, Clarke HD. Surgical treatment of early wound complications following primary total knee arthroplasty. *J Bone Joint Surg Am.* 2009 Jan;91(1):48-54.