Younger Age Is Associated with a Higher Risk of Early Periprosthetic Joint Infection and Aseptic Mechanical Failure After Total Knee Arthroplasty

John P. Meehan, MD, Beate Danielsen, PhD, Sunny H. Kim, PhD, Amir A. Jamali, MD, and Richard H. White, MD

Investigation performed at the University of California Davis Health System, Sacramento, California

Background: Although early aseptic mechanical failure after total knee arthroplasty has been reported in younger patients, it is unknown whether early revision due to periprosthetic joint infection is more or less frequent in this patient subgroup. The purpose of this study was to determine whether the incidence of early periprosthetic joint infection requiring revision knee surgery is significantly different in patients younger than fifty years of age compared with older patients following primary unilateral total knee arthroplasty.

Methods: A large population-based study was conducted with use of the California Patient Discharge Database, which allows serial linkage of all discharge data from nonfederal hospitals in the state over time. Patients undergoing primary unilateral total knee arthroplasty during 2005 to 2009 were identified. Principal outcomes were partial or complete revision arthroplasty due to periprosthetic joint infection or due to aseptic mechanical failure within one year. Multivariate analysis included risk adjustment for important demographic and clinical variables. The effect of hospital total knee arthroplasty volume on the outcomes of infection and mechanical failure was analyzed with use of hierarchical modeling.

Results: At one year, 983 (0.82%) of 120,538 primary total knee arthroplasties had undergone revision due to periprosthetic joint infection and 1385 (1.15%) had undergone revision due to aseptic mechanical failure. The cumulative incidence in patients younger than fifty years of age was 1.36% for revision due to periprosthetic joint infection and 3.49% for revision due to aseptic mechanical failure. In risk-adjusted models, the risk of periprosthetic joint infection was 1.8 times higher in patients younger than fifty years of age (odds ratio = 1.81, 95% confidence interval = 1.33 to 2.47) compared with patients sixty-five years of age or older, and the risk of aseptic mechanical failure was 4.7 times higher (odds ratio = 4.66, 95% confidence interval = 3.77 to 5.76). The rate of revision due to infection at hospitals in which a mean of more than 200 total knee arthroplasties were performed per year was lower than the expected (mean) value ($p = 0.04$).

Conclusions: Patients younger than fifty years of age had a significantly higher risk of undergoing revision due to periprosthetic joint infection or to aseptic mechanical failure at one year after primary total knee arthroplasty.

Level of Evidence: Prognostic Level III. 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: None 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 any aspect of this work. 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.

A commentary by Kelly G. Vince, MD, is linked to the online version of this article at jbjs.org.

The annual number of total knee arthroplasties continues to rise. Extrapolating the trends in the number of arthroplasties performed during the past decade, Kurtz et al. projected that by 2030, patients younger than sixty-five years of age will make up the majority of patients undergoing primary total knee arthroplasty and that up to one million total knee arthroplasties may be performed annually in patients younger than fifty-five years of age[1]. The incidence of early failure of prosthetic knees in the younger patient population has not been extensively studied to our knowledge.

Intermediate and long-term failure rates in younger patients undergoing total knee arthroplasty are higher than those in older patients, but less is known about the difference in early or short-term failure rates with respect to age[2,3]. Published studies of total knee arthroplasty outcomes have shown that early aseptic mechanical (prosthesis) failure and early periprosthetic joint infection each lead to revision surgery in approximately 1% to 2% of all patients[4-7]. However, most of those studies involved patients in the age range of sixty to eighty years. An analysis of all age groups by the Australian National Joint Replacement Registry indicated a higher cumulative revision rate at early follow-up times after primary knee replacement in younger compared with older individuals, but the analysis did not distinguish between infectious and aseptic causes of revision according to age[8].

The primary purpose of the present study was to determine whether the incidence of periprosthetic joint infection requiring revision surgery after primary unilateral total knee arthroplasty is different in patients younger than fifty years of age. We hypothesized that the one-year incidence of periprosthetic joint infection requiring revision arthroplasty would be similar in this patient group and older patients.

Materials and Methods

This was a retrospective observational study designed to analyze the outcomes of patients who had undergone a primary total knee arthroplasty (ICD-9-CM [International Classification of Diseases, 9th Revision, Clinical Modification] code 81.54) in a nonfederal hospital in California during a five-year period from January 1, 2005, to December 31, 2009. This study was approved by the California Committee for the Protection of Human Subjects and by the University of California Davis institutional review board.

Database

California hospitals must report information about all hospitalized patients after they are discharged. This Patient Discharge Database (PDD) can be used to identify temporally linked serial hospitalizations with use of an encrypted record linkage number (RLN) that is based on the patient's Social Security Number. Record linkage allows late complications to be identified even if the patient is hospitalized in a different hospital in the state. All PDD records include demographic information, a principal medical diagnosis, up to twenty-four additional "secondary" diagnoses, and a principal procedure and up to twenty secondary procedures, all coded with use of the ICD-9-CM.

Assembly of the Total Knee Arthroplasty Cohort

All patients coded as having only one total knee arthroplasty performed during the study period were identified. We then minimized the number of patients who may have had a primary total knee arthroplasty prior to the study period by excluding all patients coded as having had a primary total knee arthroplasty (ICD-9-CM 81.54), a revision total knee arthroplasty (81.55 or 00.80 to 00.84), or any history of a prior total knee arthroplasty (V43.65) at any discharge from 1991 to 2005. We also excluded all patients with a second primary total knee arthroplasty (81.54) within one year after the index total knee arthroplasty and those coded as having cancer (190.x to 209.x) or a rheumatic disease (714.xx, 710.xx, 696.x). (For all codes, "x" indicates that any integer was acceptable.)

Outcomes

Outcomes were prespecified with use of specific ICD-9-CM codes. These outcomes included specific major orthopaedic complications that required hospitalization coupled with specific procedures occurring within 365 days after the index total knee arthroplasty. The principal outcome of interest was a major periprosthetic joint infection leading to total joint revision surgery, tibial liner removal, arthrotomy, debridement, synovectomy, or "other excision," arthrotomy for removal of the prosthesis, or above-the-knee amputation from thirty to 365 days after the index operation.

We also determined the incidence of aseptic mechanical failure. For patients coded as having only mechanical failure, we included all cases of revision knee arthroplasty or revision of the femoral component, patellar component, tibial component, or tibial liner within one year after the index arthroplasty.

For each knee arthroplasty failure, we distinguished between infectious and mechanical causes with use of the medical diagnosis codes that accompanied the revision knee procedure code. To be categorized as an infection-related revision, we required (1) a code for infection due to an internal joint prosthesis (996.66); infection due to a device, implant, or graft (996.67); other postoperative infection (998.59); postoperative seroma (998.51); or periostitis without mention of osteomyelitis (730.36), coupled with either (2) a complete or partial knee arthroplasty revision (81.55, 00.80 through 00.84, 80.06, or 84.17) or (3) arthrotomy (80.16), excisional debridement (86.22), synovectomy (80.76), or other local excision or destruction (80.86) performed more than thirty days after the index total knee arthroplasty. A minor periprosthetic joint infection was defined as (1) one of the codes for infection, coupled with (2) liner removal (00.84), arthrotomy (80.16), debridement (86.22), synovectomy (80.76), or other excision (80.86) within thirty days after the total knee arthroplasty, without subsequent revision knee arthroplasty.

Mechanical complications leading to revision consisted of (1) a mechanical complication of an orthopaedic device (996.4x), ankylosis of the joint (718.56), recurrent dislocation (718.36), complications cause by a joint prosthesis (996.77), or a complication due to an internal orthopaedic device (996.78), coupled with (2) revision arthroplasty (81.55), removal of an implanted device (78.67), internal femoral fixation without a fracture (78.55), other partial ostectomy (77.86), closed reduction without internal fixation (79.06), or division of the joint capsule, ligament, or cartilage (80.46).

As a means of assessing the external validity of the data, we also included a third outcome measure, major cardiovascular complications within thirty days, which was a composite of coronary outcomes (acute myocardial infarction, coronary angioplasty/stenting, or coronary artery bypass surgery), postoperative shock, or death during this time period.

Statistics

Age was categorized as younger than fifty years, fifty to sixty-four years, or sixty-five years of age or older. Race/ethnicity was categorized as Hispanic, black, Asian, white, and "other," which included mixed race and Native Americans. Logistic regression was used to adjust for demographic variables and the number of chronic comorbidities. The effect of annual hospital total knee arthroplasty volume was evaluated with use of hierarchical modeling, with the hospital as a random effect. Specifically, the number of observed periprosthetic joint infections in hospitals that performed <50, 50 to 100, 101 to 200, or >200 such procedures per year during the study period was compared with the expected (mean) number predicted with use of the risk-adjusted model.

Categorical data were analyzed with use of chi-square testing. Significance testing for trends in categorical data was performed with use of the Cochran-Armitage test for trend with a two-sided p value.

TABLE I Clinical Characteristics of Patients with Revision Due to Infection or Aseptic Mechanical Failure within One Year After Total Knee Arthroplasty (TKA)

		Major Knee Infection			Aseptic Mechanical Failure		
Risk Factor	No. of Patients	No. Revised	Percentage	P Value for Trend*	No. Revised	Percentage	P Value for Trend*
Total	120,538	983	0.82		1385	1.15	
Patient age in yr			†	<0.001		†	<0.001
<50	5301	72	1.36		185	3.49	
50-64	40,667	366	0.90		640	1.57	
≥65	74,570	545	0.73		560	0.75	
Sex			†				
F	74,482	506	0.68		844	1.13	
M	46,051	477	1.04		541	1.17	
Race/ethnicity			†			†	
White	87,738	696	0.79		999	1.14	
Hispanic	17,733	153	0.86		177	1.00	
Black	6249	76	1.22		123	1.97	
Asian	4801	24	0.50		37	0.77	
Other	4017	34	0.85		49	1.22	
Annual hospital TKA volume			†	<0.001		‡	0.003
<50	9015	104	1.15		123	1.36	
50 to 100	16,736	171	1.02		218	1.30	
101 to 200	37,746	308	0.82		431	1.14	
>200	57,041	400	0.70		614	1.08	
Calendar year			†	0.02		§	0.39
2005	22,181	212	0.96		270	1.22	
2006	23,335	218	0.93		281	1.20	
2007	24,393	174	0.71		258	1.06	
2008	25,226	185	0.73		280	1.11	
2009	25,403	194	0.76		296	1.17	
No. of comorbidities			†	<0.001		§	0.01
0	51,535	328	0.64		568	1.10	
1	38,094	284	0.75		433	1.14	
2	18,580	189	1.02		216	1.16	
3	7687	100	1.30		99	1.29	
4	2925	51	1.74		37	1.26	
≥5	1717	31	1.81		32	1.86	
Comorbidity							
Anemia	18,102	198	1.09#		220	1.22§	
Heart failure	4170	67	1.61#		47	1.13†	
Pulmonary obst. dis.	18,824	201	1.07#		250	1.33§	
Depression	12,189	137	1.12#		181	1.48#	
Diabetes	24,097	267	1.11#		258	1.07§	
Obesity	26,327	289	1.10#		351	1.33#	
Peripheral vascular dis.	3413	52	1.52#		32	0.94§	
Psychosis	2726	45	1.65#		58	2.13#	
Pulmonary circ. dis.	823	3	0.36§		8	0.97§	
Renal failure	4027	46	1.14†		40	0.99§	
Valvular dis.	4814	41	0.85§		47	0.98§	

*Cochran-Armitage test for trend. †$P < 0.001$ (chi-square, within risk-group difference). ‡$P < 0.05$ (chi-square). §$P > 0.05$ (chi-square). #$P < 0.001$ (chi-square).

TABLE II Risk-Adjusted Results for Major Periprosthetic Infection

Risk Factor	OR	95% CI	P Value
Age in yr			
<50	1.81	1.33-2.47	0.003
50-64	1.20	1.01-1.42	0.038
≥65	Ref.		
Sex			
F	Ref.		
M	1.60	1.31-1.97	0.01
Race/ethnicity			
White	Ref		
Hispanic	1.01	0.83-1.22	0.958
Black	1.38	1.06-1.80	0.023
Asian	0.68	0.43-1.06	0.085
Other	1.06	0.72-1.56	0.743
No. of comorbidities*			
0	Ref.		
1	1.21	1.02-1.44	0.034
2	1.68	1.37-2.05	<0.001
3	2.15	1.67-2.77	<0.001
≥4	2.92	2.23-3.84	<0.001

*Elixhauser comorbidity count.

Source of Funding
No external funding was received for this study.

Results

The clinical characteristics of the patient cohort and patients who underwent revision as a result of infection or mechanical malfunction within one year are shown in Table I. We identified 120,538 patients who underwent a primary unilateral total knee arthroplasty during the five-year time period and did not appear to have undergone either a prior total knee arthroplasty performed subsequent to 1990 or a second primary total knee arthroplasty performed during the first year after the index total knee arthroplasty. One or more total knee arthroplasties were performed at approximately 300 hospitals in California.

Overall, 0.82% (983) of the patients required revision knee surgery within one year because of a major periprosthetic joint infection. The incidence was highest (1.36%, seventy-two patients) among those younger than fifty years of age. The rate in this age group was approximately twice that in patients sixty-five years of age or older (0.73%, 545 patients). The one-year incidence of major periprosthetic joint infection decreased significantly ($p < 0.001$) with increasing age group.

Overall, aseptic mechanical failure requiring revision surgery within one year occurred in 1.15% (1385) of the patients. The highest incidence of 3.49% (185 patients) was among patients younger than fifty years of age, and the incidence decreased significantly ($p < 0.001$) with increasing age group, reaching 0.75% (560 patients) among those sixty-five years of age or older.

In each of the age groups, the incidence of infection was significantly higher ($p < 0.001$) in men (1.04%, 477 patients) than in women (0.68%, 506 patients), but there was no difference in the incidence of aseptic mechanical failure, which was 1.17% (541 patients) in men compared with 1.13% (844 patients) in women. There was a significant decrease in the incidence of major periprosthetic knee infection from 2005 (0.96%) to 2009 (0.76%, $p = 0.02$) but no significant change in the incidence of aseptic mechanical failure.

There was a steady increase in the one-year incidence of periprosthetic joint infection with an increase in the number of chronic comorbid conditions present (from 0.64% for patients with no comorbidity to 1.81% for those with five or more comorbidities, $p < 0.001$). The results of the multivariate logistic regression modeling of risk factors for periprosthetic joint infection are shown in Table II. Significant predictors of knee revision surgery due to infection included an age younger than fifty years (odds ratio [OR] = 1.81, 95% confidence interval [CI] = 1.33 to 2.47, relative to an age of sixty-five years or over), male sex (OR = 1.60, 95% CI = 1.31 to 1.97), and black race (OR = 1.38 relative to non-Hispanic whites, 95% CI = 1.06 to 1.80). Risk (relative to zero comorbidities) increased steadily with the number of chronic comorbidities, from OR = 1.21 (95% CI = 1.02 to 1.44) for one comorbidity to OR = 2.92 (95% CI = 2.23 to 3.84) for four or more. The comorbidities associated with the highest risk of periprosthetic joint infection were psychosis (OR = 1.65, 95% CI = 1.21 to 2.25), congestive heart failure (OR = 1.64, 95% CI = 1.26 to 2.13), obesity (OR = 1.33, 95% CI = 1.15 to 1.54), and diabetes (OR = 1.31, 95% CI = 1.13 to 1.52). Modeling the hospital as a random effect, the ratio of the number of observed cases of periprosthetic knee infection requiring revision to the expected (mean) number (the O/E ratio) was significantly lower (0.80, 95% CI = 0.64 to 0.99) for hospitals that performed >200 total knee arthroplasties per year (Table III).

In the multivariate model predicting the risk of revision knee arthroplasty due to aseptic mechanical failure (Table IV), the risk was significantly higher for patients younger than fifty years of age compared with patients sixty-five years of age or older (OR = 4.66, 95% CI = 3.77 to 5.76, $p < 0.01$) and for blacks compared with non-Hispanic whites (OR = 1.44, 95% CI = 1.17 to 1.79, $p = 0.002$). The presence of four or more

TABLE III Effect of Hospital Volume on Major Periprosthetic Infection*

Annual Total Knee Arthroplasty Volume	O/E Ratio	95% CI	P Value
<50	1.25	0.95-1.56	0.13
50-100	1.13	0.89-1.43	0.31
101-200	0.92	0.73-1.15	0.45
>200	0.80	0.64-0.99	0.04

*The hospital was treated as a random effect.

TABLE IV Risk-Adjusted Results for Aseptic Mechanical Failure

Risk Factor	OR	95% CI	P Value
Age in yr			
<50	4.66	3.77-5.76	<0.01
50-64	2.09	1.81-2.41	<0.01
≥65	Ref.		
Sex			
F	Ref.		
M	1.00	0.84-1.19	0.98
Race/ethnicity			
White	Ref.		
Hispanic	0.83	0.69-0.99	0.04
Black	1.44	1.17-1.79	<0.01
Asian	0.76	0.53-1.10	0.14
Other	1.05	0.76-1.44	0.77
No. of comorbidities*			
0	Ref.		
1	1.04	0.91-1.20	0.53
2	1.06	0.89-1.27	0.46
3	1.17	0.92-1.49	0.18
≥4	1.39	1.05-1.84	0.03

*Elixhauser comorbidity count.

TABLE V Effect of Hospital Volume on Aseptic Mechanical Failure*

Annual Total Knee Arthroplasty Volume	O/E Ratio	95% CI	P Value
<50	1.05	0.92-1.20	0.47
50-100	1.07	0.94-1.21	0.32
101-200	0.98	0.87-1.09	0.66
>200	0.92	0.82-1.03	0.13

*The hospital was treated as a random effect.

comorbidities was associated with a significantly higher risk of revision compared with no comorbidities (OR = 1.39, 95% CI = 1.05 to 1.84, p = 0.03). Sex was not a risk factor for aseptic mechanical failure. Greater hospital volume was also not a predictor of a lower incidence of aseptic mechanical failure; the number of such failures decreased as hospital volume increased, but in each category the observed failure rate did not differ significantly from that expected on the basis of all hospital volumes combined (Table V).

The incidence of the composite outcome of death or a major cardiovascular complication within thirty days after total knee arthroplasty was low, 0.58% (95% CI = 0.54% to 0.62%). In the multivariate model, the risk increased significantly (p < 0.001) with increasing age; was significantly higher in men (OR = 2.50, 95% CI = 1.96 to 3.20); and was strongly associated with the number of comorbidities, increasing from OR = 1.65 (95% CI = 1.29 to 2.10) for one comorbidity (relative to none) to OR = 7.91 (95% CI = 5.97 to 10.48) for four or more. Higher hospital total knee arthroplasty volume was associated with a lower incidence, but the ratio between the number of observed cases for hospitals performing >200 such procedures per year and the expected (mean) number did not quite reach significance (O/E ratio = 0.84, 95% CI = 0.70 to 1.00, p = 0.052).

In order to allow for a more direct comparison of these results with registry data, we performed an additional analysis of patients in California who underwent revision knee surgery due to periprosthetic joint infection or due to aseptic mechanical failure within two years (see Appendix). The results incidence of periprosthetic joint infection and incidence of aseptic mechanical failure within two years were likewise greater in patients younger than fifty years of age.

Discussion

Much of the information published regarding the causes of total knee arthroplasty failure and indications for revision in the United States has come from case series from a single center, cohort studies from large academic institutions, or administrative databases such as the Nationwide Inpatient Sample (NIS) and the Medicare 5% national sample administrative data set[9-14]. Many of these studies involve primarily patients who are sixty-five years or older, and most describe only intermediate to long-term failure rates and mechanisms.

Elevated intermediate and long-term rates of total knee arthroplasty revision due to aseptic mechanical failure have been described in younger patients[15-18]. Typically, the elevated rate is attributed to the greater activity level in these younger individuals and to the cumulative stresses on the prosthesis, bone, and soft-tissue interfaces over many years.

Less is known about the relationship between younger age and the short-term outcomes of total knee arthroplasty. Julin et al. used the Finnish Arthroplasty Register, which records data prospectively and captures 96% of primary knee replacements performed in Finland, to identify younger age (especially less than fifty-five years of age) as a risk factor for revision of total knee arthroplasty within five years due to aseptic mechanical failure[19]. Their primary outcome measure was the prosthesis survival rate, which they described as the proportion of prostheses surviving without revision during the follow-up period. However, they failed to identify any association between patient age and failure specifically due to periprosthetic joint infection. Bohm et al. reported findings from the Canadian Institute for Health Information Discharge Abstract Database regarding >65,000 hip and knee arthroplasties performed from 2005 to 2006[20]. They concluded that the rehospitalization rate due to infection within the first year after knee replacement was significantly higher (p < 0.001) in men (1.6%) than in women (1.2%). They also stated that infection rates did not vary significantly according to age.

With the American Joint Replacement Registry still in its early stages, the ability to identify a complication within a large

population of patients who undergo a specific procedure has typically involved use of the NIS database or the Medicare 5% national sample administrative data set. For joint replacement procedures, however, these data sets have limitations because they do not include information on all patients who underwent the procedure. Instead, they use sampling to extrapolate findings to the larger population. Also, prior to 2005, ICD-9-CM codes were not used to identify the specific type of prosthetic joint failure.

We used the California PDD to identify and capture all patients (not limited to Medicare beneficiaries) who underwent primary total knee arthroplasty from January 1, 2005, to December 31, 2009, and subsequent revision due to either periprosthetic infection or aseptic mechanical failure within one year. This database provides the unique ability to identify and serially follow all patients who are hospitalized at any nonfederal hospital in California, regardless of whether the hospital was the site of the primary or the revision procedure. With the resulting data set, we identified younger age as an independent risk factor for both periprosthetic joint infection and aseptic mechanical failure within one year.

To our knowledge, this is the first study to document a higher incidence of early revision due to periprosthetic joint infection after knee arthroplasty in patients younger than fifty years of age. Patients who were younger than fifty years of age when they underwent the primary knee replacement were almost twice as likely to require revision surgery within one year due to periprosthetic joint infection compared with patients who were sixty-five years of age or older. Also, patients who were younger than fifty years of age were almost five times as likely to undergo revision due to aseptic mechanical failure within one year compared with patients sixty-five years of age or older.

One potential explanation for the higher incidence of revision arthroplasty due to periprosthetic joint infection in younger patients is the higher prevalence of secondary (e.g., posttraumatic) osteoarthritis in younger patients compared with primary osteoarthritis in older patients. Patients with posttraumatic osteoarthritis frequently have undergone an arthrotomy with open reduction and internal fixation of the traumatic injury. A previous arthrotomy is a recognized risk factor for periprosthetic knee infection[21]. However, a clear relationship between previous arthrotomy and aseptic mechanical failure has not been established. Prosthesis fixation issues, such as the use of fixation without cement, have also been implicated as a potential cause of aseptic mechanical failure in the young patient[2].

In the present analysis, we were also able to evaluate the effect of hospital volume and the specific outcomes of periprosthetic joint infection and aseptic mechanical failure. In agreement with previous studies, higher-volume hospitals (>200 total knee arthroplasties per year) had a lower incidence of early periprosthetic joint infections compared with lower-volume hospitals[5,22]. We did not demonstrate a similar relationship between higher hospital volume and a lower rate of early aseptic mechanical failure, although we did observe a trend. Manley et al. also did not find a relationship between hospital total knee arthroplasty volume and early aseptic mechanical failure in the Medicare population, although they did find that patients treated at the lowest-volume hospitals (one to twenty-five such procedures per year) had a higher risk of revision at five and eight years compared with those treated at the highest-volume hospitals (>200 procedures)[14].

The strengths of the present study include the inclusion of all patients who underwent primary total knee arthroplasty in California during a five-year time period and the ability to identify all patients who underwent revision surgery in the state, regardless of where the primary arthroplasty had been performed. All complications were defined explicitly with use of ICD-9-CM coding[23,24], the major orthopaedic complication codes used have high predictive value[25], and these codes were coupled with major procedure codes, making case identification even more reliable. The limitations of the study include the retrospective design, reliance on administrative data, and inability to account for the effect of individual surgeons. We also could not adjust for potential confounders such as the severity of the joint disease, fixation with and without cement, and the type or duration of antibacterial prophylaxis used.

In conclusion, the results of this study revealed that younger patients who underwent a primary total knee arthroplasty had higher one-year and two-year incidences of both periprosthetic joint infection and aseptic mechanical failure requiring revision arthroplasty. Thus, performing this procedure in individuals younger than fifty years of age should be approached with caution. The high incidence of early infectious and mechanical failures warrants further investigation to determine which specific patient characteristics in this younger age group contribute to their higher risk. The finding of a lower incidence of periprosthetic joint infection at high-volume hospitals is consistent with previous studies and supports the concept of utilizing specialty hospitals and hospitals with specialized surgical services as a means to reduce complications.

Appendix

(eA) A table showing the clinical characteristics of patients undergoing revision due to infection or aseptic mechanical failure within two years after total knee arthroplasty is available with the online version of this article as a data supplement at jbjs.org. ■

John P. Meehan, MD
Department of Orthopaedic Surgery,
University of California Davis,
4860 Y Street, Suite 3800,
Sacramento, CA 95817.
E-mail address: John.Meehan@ucdmc.ucdavis.edu

Beate Danielsen, PhD
Health Information Solutions,
2425 Clubhouse Drive,
Rocklin, CA 95765

Sunny H. Kim, PhD
School of Medicine,
University of California Davis,
2921 Stockton Boulevard, Suite 1400,
Sacramento, CA 95817

Amir A. Jamali, MD
Joint Preservation Institute,
2825 J Street,
Suite 440,
Sacramento, CA 95816

Richard H. White, MD
Department of Medicine,
University of California Davis,
Suite 2400, PSSB, 4150 V Street,
Sacramento, CA 95817

References

1. Kurtz SM, Lau E, Ong K, Zhao K, Kelly M, Bozic KJ. Future young patient demand for primary and revision joint replacement: national projections from 2010 to 2030. Clin Orthop Relat Res. 2009 Oct;467(10):2606-12. Epub 2009 Apr 10.

2. Paxton EW, Namba RS, Maletis GB, Khatod M, Yue EJ, Davies M, Low RB Jr, Wyatt RW, Inacio MC, Funahashi TT. A prospective study of 80,000 total joint and 5000 anterior cruciate ligament reconstruction procedures in a community-based registry in the United States. J Bone Joint Surg Am. 2010 Dec;92(Suppl 2):117-32.

3. Harrysson OL, Robertsson O, Nayfeh JF. Higher cumulative revision rate of knee arthroplasties in younger patients with osteoarthritis. Clin Orthop Relat Res. 2004 Apr;421:162-8.

4. Kurtz SM, Ong KL, Lau E, Bozic KJ, Berry D, Parvizi J. Prosthetic joint infection risk after TKA in the Medicare population. Clin Orthop Relat Res. 2010 Jan;468(1):52-6. Epub 2009 Aug 08.

5. Katz JN, Barrett J, Mahomed NN, Baron JA, Wright RJ, Losina E. Association between hospital and surgeon procedure volume and the outcomes of total knee replacement. J Bone Joint Surg Am. 2004 Sep;86(9):1909-16.

6. Losina E, Katz JN. Total knee arthroplasty on the rise in younger patients: are we sure that past performance will guarantee future success? Arthritis Rheum. 2012 Feb;64(2):339-41.

7. Weinstein AM, Rome BN, Reichmann WM, Collins JE, Burbine SA, Thornhill TS, Wright J, Katz JN, Losina E. Estimating the burden of total knee replacement in the United States. J Bone Joint Surg Am. 2013 Mar 6;95(5):385-92.

8. Australian Orthopaedic Association National Joint Replacement Registry. Hip and knee arthroplasty annual report. https://aoanjrr.dmac.adelaide.edu.au/annual-reports-2012. Accessed 2013 Sep 16.

9. Bozic KJ, Kurtz SM, Lau E, Ong K, Chiu V, Vail TP, Rubash HE, Berry DJ. The epidemiology of revision total knee arthroplasty in the United States. Clin Orthop Relat Res. 2010 Jan;468(1):45-51. Epub 2009 Jun 25.

10. Bozic KJ, Lau E, Kurtz S, Ong K, Berry DJ. Patient-related risk factors for post-operative mortality and periprosthetic joint infection in medicare patients undergoing TKA. Clin Orthop Relat Res. 2012 Jan;470(1):130-7.

11. Fehring TK, Odum S, Griffin WL, Mason JB, Nadaud M. Early failures in total knee arthroplasty. Clin Orthop Relat Res. 2001 Nov;392:315-8.

12. Callahan CM, Drake BG, Heck DA, Dittus RS. Patient outcomes following tricompartmental total knee replacement. A meta-analysis. JAMA. 1994 May 4; 271(17):1349-57.

13. 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.

14. Manley M, Ong K, Lau E, Kurtz SM. Total knee arthroplasty survivorship in the United States Medicare population: effect of hospital and surgeon procedure volume. J Arthroplasty. 2009 Oct;24(7):1061-7. Epub 2008 Nov 01.

15. Robertsson O, Knutson K, Lewold S, Lidgren L. The Swedish Knee Arthroplasty Register 1975-1997: an update with special emphasis on 41,223 knees operated on in 1988-1997. Acta Orthop Scand. 2001 Oct;72(5):503-13.

16. Gioe TJ, Novak C, Sinner P, Ma W, Mehle S. Knee arthroplasty in the young patient: survival in a community registry. Clin Orthop Relat Res. 2007 Nov;464:83-7.

17. Gioe TJ, Killeen KK, Grimm K, Mehle S, Scheltema K. Why are total knee replacements revised?: analysis of early revision in a community knee implant registry. Clin Orthop Relat Res. 2004 Nov;428:100-6.

18. Australian Orthopaedic Association National Joint Replacement Registry. Hip and knee arthroplasty. Annual report 2008. https://aoanjrr.dmac.adelaide.edu.au/documents/10180/42662/Annual%20Report%202008?version=1.1&t=1349406277970. Accessed 2009 Apr 28.

19. Julin J, Jämsen E, Puolakka T, Konttinen YT, Moilanen T. Younger age increases the risk of early prosthesis failure following primary total knee replacement for osteoarthritis. A follow-up study of 32,019 total knee replacements in the Finnish Arthroplasty Register. Acta Orthop. 2010 Aug;81(4):413-9.

20. Bohm ER, Dunbar MJ, Frood JJ, Johnson TM, Morris KA; Rehospitalizations, early revisions, infections, and hospital resource use in the first year after hip and knee arthroplasties. J Arthroplasty. 2012 Feb;27(2):232-7. Epub 2011 Jul 14.

21. Ayers DC, Dennis DA, Johanson NA, Pellegrini JVD. Instructional course lectures, the American Academy of Orthopaedic Surgeons - common complications of total knee arthroplasty. J Bone Joint Surg Am. 1997;79(2):278-311.

22. Hervey SL, Purves HR, Guller U, Toth AP, Vail TP, Pietrobon R. Provider volume of total knee arthroplasties and patient outcomes in the HCUP-Nationwide Inpatient Sample. J Bone Joint Surg Am. 2003 Sep;85(9):1775-83.

23. Birman-Deych E, Waterman AD, Yan Y, Nilasena DS, Radford MJ, Gage BF. Accuracy of ICD-9-CM codes for identifying cardiovascular and stroke risk factors. Med Care. 2005 May;43(5):480-5.

24. White RH, Garcia M, Sadeghi B, Tancredi DJ, Zrelak P, Cuny J, Sama P, Gammon H, Schmaltz S, Romano PS. Evaluation of the predictive value of ICD-9-CM coded administrative data for venous thromboembolism in the United States. Thromb Res. 2010 Jul;126(1):61-7. Epub 2010 Apr 28.

25. Bozic KJ, Chiu VW, Takemoto SK, Greenbaum JN, Smith TM, Jerabek SA, Berry DJ. The validity of using administrative claims data in total joint arthroplasty outcomes research. J Arthroplasty. 2010 Sep;25(6)(Suppl):58-61.Epub 2010 Jun 08.